Watershed Protection MASTER PLAN

FY 2015 | 2016

WATERSHED PROTECTION

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Acknowledgments

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Preface

Austin and Central Texas are known and celebrated for creeks, rivers, lakes, and springs. Access to an abundant, reliable, and clean source of water played a key role in the original decision in 1835 to locate the city just downstream of Barton Springs along the Colorado River and to select it as the state's capital in 1839. And today Austin's water features continue to be the source of intense pride for its residents and a powerful magnet for visitors, new residents, and businesses.

Today, with Austin being among the fastest growing communities in the United States, many challenges remain in protecting Austin's watersheds, waterways, and water supply. This Watershed Protection Master Plan presents a systematic, objective approach to protecting these invaluable resources. It serves as the guiding document for the activities of the City of Austin's Watershed Protection Department (WPD).

The first edition of this Master Plan was completed and approved by City Council in 2001. Since that time, much progress has been made in addressing Austin's watershed challenges, but much work remains. The 2013 and 2015 Halloween and Memorial Day Floods underscore the ongoing need to effectively prepare and respond to adversity. This Master Plan assesses the continuing challenges and documents the detailed process by which WPD prioritizes its work to meet these challenges.

This present edition, updated in August 2016, greatly expands the scope of the area evaluated for problem identification and solution proposal, building on the original 17 core watersheds studied in 2001 to present key parameters in 49 watersheds. Appendix A presents a full summary of all the important changes and improvements of this edition from the original 2001 Master Plan and 2015 edition.

While study methods have improved over time, WPD's mission and focus remains the same—to protect the lives, property, and environment of our community by reducing the impact of flooding, erosion, and water pollution. We appreciate your interest in our work and encourage your feedback and suggestions as we continuously seek cost-effective ways to protect and restore Austin's beloved natural environment.

Joseph G. Pantalion, Director
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Executive Summary

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Introduction

For more than three decades, the City of Austin has been recognized as a national leader in watershed protection. From the 1970s to today, the City's flood, erosion, and water quality protection efforts have matured with the passage of protective regulations, development of comprehensive programs, and with dedicated funding for capital projects.

This Watershed Protection Master Plan outlines a framework for the Watershed Protection Department (WPD) to address existing problems and prepare for future challenges. It uses the following approach:

1. Establish watershed protection goals;
2. Evaluate watershed conditions relative to the goals;
3. Identify problem locations and prioritize by problem severity; and
4. Identify preferred solutions to address problems.

Each component is presented below and discussed in detail in the full Master Plan.

Figure EX-1 Lady Bird Lake

Watershed Protection Goals

This Master Plan seeks to carry out **WPD's mission: to protect the lives, property, and environment of our community by reducing the impact of flooding, erosion, and water pollution.** The Master Plan was first completed and approved by City Council in 2001. It focused on 17 Phase 1 watersheds in Austin's core, comprising the areas with the oldest development and most dense population. This present Master Plan, updated in August 2016, expands the focus to include virtually all watersheds in Austin's jurisdiction. The original Phase 1 and the additional Phase 2 watersheds are shown in Figure EX-2.

Sections 1 and 2 present WPD's mission and management goals. The goals are as follows:

1. Protect lives and property by reducing the impact of flood events.
2. Protect channel integrity and prevent property damage resulting from erosion.
3. Protect and improve Austin's waterways and aquifers for citizen use and support of aquatic life.
4. Improve the urban environment by fostering additional beneficial uses of waterways and drainage facilities.
5. Meet or exceed all local, state, and federal permit and regulatory requirements.
6. Maintain the integrity and function of Utility Assets.
7. Optimize City resources by integrating flood, erosion, and water quality control measures.

Each goal is further defined by one or more objectives. These objectives are found in Table 2.4-1 in Section 2.

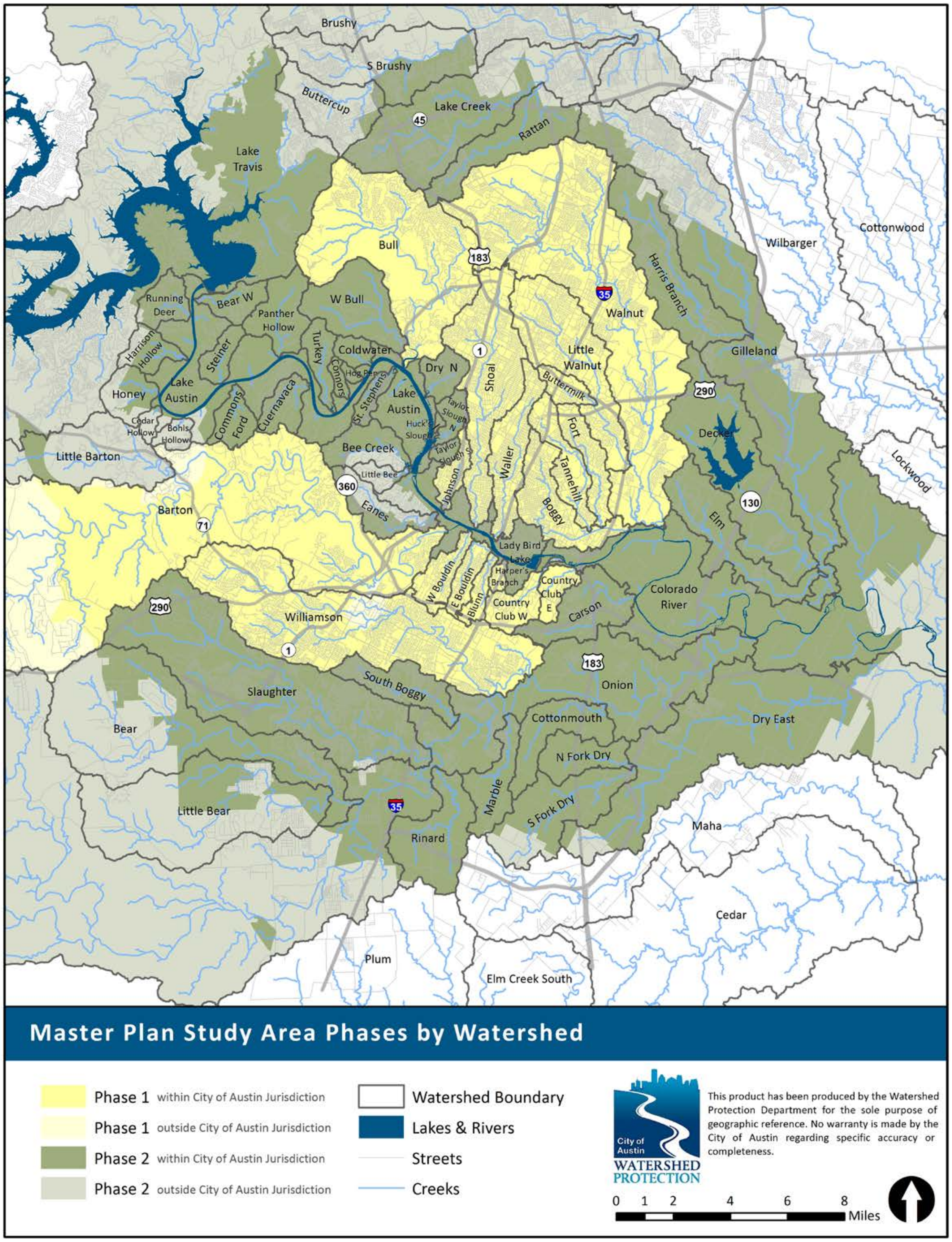

Figure EX-2 Master Plan Study Area Phases by Watershed

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Problem Area Identification: Flood, Erosion, and Water Quality

WPD has three primary "missions": Flood Mitigation, Erosion Control, and Water Quality Protection. WPD performs technical studies to characterize conditions for each of these missions in the watersheds within its jurisdiction. These studies identify Problem Areas where watershed protection goals are not being achieved. This approach enables direct comparisons between watersheds and promotes consistency among the three missions. Technical assessments have been completed for all Phase 1 and many Phase 2 watersheds as follows: Creek Flood (30 watersheds); Erosion Control (26 watersheds); and Water Quality Protection (49 watersheds). Citizen complaint data and limited technical modeling assessments are available for Local Flood systems.

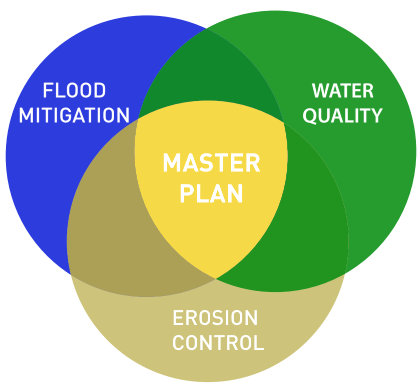

Figure EX-3 WPD's three primary missions

Section 3 introduces the Problem Area identification and prioritization process. Sections 4 to 7 present methodologies and results to quantify and prioritize Problem Areas for Creek Flood, Local Flood, Erosion Control, and Water Quality Protection, respectively. For each mission, "problem scores" are developed which assign a numeric value to watershed problems, such as individual erosion sites or structures in floodplains. Problem scores range from 0 to 100, with 0 reflecting no problem and 100 representing the worst problem identified (Local Flood uses a different scoring system). Problem scores are a function of problem severity and the number and type of resources impacted. To enable comparisons across geographic areas, problem scores can be aggregated into larger units, such as stream reaches, project groupings, or even entire watersheds.

A central principle of this Master Plan is that the most severe problems should be considered first for solutions identification. This plan therefore outlines a "needs-based" prioritization approach using best available technical data. (At later stages of evaluation, additional factors such as solution feasibility, timing, and opportunity to share resources are also considered.)

The technical assessment methodologies used to characterize watershed conditions for each WPD mission are described below.

Flood Mitigation

Austin is located in an area known as "Flash Flood Alley." Its unique combination of intense rainstorms, steep slopes, and slow-draining soils make it especially prone to severe flooding conditions. Most people who live in Austin have witnessed firsthand or seen reports of flooding of homes, roads, or other property. Floods in 1981, 1991, 1998, 2001, 2010, 2013, and 2015 are reminders of the public safety and property hazards associated with flooding. In nearly every decade there is a record of significant flood events. **The WPD goal for Flood Mitigation is to protect lives and property by reducing the impact of flood events.** This Master Plan details how flooding problem areas are identified, prioritized, and addressed using capital, programmatic, and regulatory solutions.

Flooding can occur in both the primary and secondary drainage systems. Assessment methods to catalogue **creek flooding** problems associated with the primary system (major

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creeks and their tributaries) are presented in Section 4. Methods used to investigate **local flooding** associated with the secondary drainage system (storm drains and minor channels) are presented in Section 5.

Creek Flood Assessments. Flooding problems in major creek systems are identified using hydrologic and hydraulic (H&H) computer models. These models predict when flood levels become high enough to overflow creek banks and flood nearby structures (e.g., bridges, culverts, homes, and other buildings). Over the past 35 years, the City has developed floodplain models and maps for almost all major City-managed watersheds. Flood assessments identify the depth, velocity, and frequency of flooding of all structures and roadway crossings. This problem severity data is then used to calculate flood problem scores, weighted by the frequency of flooding and the type of resource threatened. For example, the same type of structure in the 2-year floodplain (50% chance of flooding in any given year) will have a higher score than if it was in the 100-year floodplain (1% chance of flooding). A hospital would be given a higher score than a parking garage, and so forth.

Figure EX-4 Flooding on Onion Creek, 2013

WPD assesses creek flood risk for 30 watersheds entirely or partially within Austin's full purpose jurisdiction (city limits). WPD's models have estimated the number of structures and street crossings that are within the 100-year floodplain, as well as the number of structures that will be inundated during a 2-, 10-, 25-, and 100-year flood (see Table EX-1 below). The results of this modeling are further discussed in Section 4.

Table EX-1 Estimates of Structures and Roadways in 100-year Floodplain and at Risk of Inundation, Full Purpose and Extraterritorial Jurisdiction (ETJ) (Oct.2015)

	Located in 100-yr Floodplain	Inundated in Floodplain			
		2-yr	10-yr	25-yr	100-yr
Structures (full purpose)	4,788*	37	303	793	2,207
Structures (ETJ)	667	18	167	306	465
Roadway Crossings (full purpose)	580	94	235	310	393
Roadway Crossings (ETJ)	132	45	69	82	94

** An additional 215 structures from Onion and 28 from Williamson have been removed from the floodplain as of July 2016 via property buyouts; the resulting total number of structures in the floodplain in the full-purpose jurisdiction has thus fallen from 4,788 to 4,545.*

Tables 4.6-3 and 4.6-6 in Section 4 present the Top 20 Creek Flood Problem Areas for structure flooding and street crossing flooding, respectively. As expected, the majority of these problem areas are in the older urban core or older outlying development, both built during a time that predated a modern understanding of floodplain delineation.

Local Flood Assessments. Local flooding occurs when rainfall events overwhelm smaller drainage systems, such as storm drain pipes and small open channels. WPD uses multiple sources of data to assess local drainage problems, including data from citizen complaints, GIS, video inspections, field surveys, and one- and two-dimensional storm drain models. At present, citizen complaint information is relied on for problem identification in many areas, but modeling efforts are progressing. One-

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dimensional models have been completed for 43% of the local drainage systems. However, with approximately 1,100 miles of drainage systems to model, it will require multiple years to complete.

The annual prioritization uses citizen complaint data that has been investigated by staff in the field. Complaint locations are aggregated into clusters of five or more locations within 150 feet of each other. The cluster areas are then reviewed and developed into a final problem area for potential storm drain system improvements. These are the basis for prioritizing both problems and potential capital solutions. Table 5.7-1 in Section 5 presents the Top 20 Local Flood Problem Areas. Almost all of these areas are either in older urban core or outlying annexed areas served by drainage systems that predate a modern understanding of adequate drainage design. Beginning in 1977, the City required all new systems to be built according to formal drainage criteria, which greatly reduced the creation of undersized and substandard systems.

The central urban core is also the epicenter of recent redevelopment and infill development. This increases the pressure to upgrade old and undersized local drainage systems. In 2012, WPD initiated an intensive planning study to assess existing drainage systems in the West Bouldin watershed, which runs along South Lamar Boulevard between Ben White Boulevard and Lady Bird Lake. This study serves as a pilot study to see if additional watersheds should be approached in a similarly focused manner. Future updates of this Master Plan will report on its findings and practicality for citywide application.

Erosion Control

The WPD goal for Erosion Control is to protect channel integrity and prevent property damage resulting from erosion. Many of Austin's streams exhibit erosion, especially in the older urban core in areas developed prior to the advent of protective regulations. Erosion problems typically stem from increased stormwater runoff from urbanization and/or placement of structures and utilities too close to stream banks. Excessive channel erosion not only threatens creekside resources but also harms water quality and aquatic ecosystems.

To help identify these concerns, WPD staff conduct Erosion Assessments of existing and potential future threats to buildings, roads, trees, utilities, fences, and other resources. Field teams also note areas where a significant loss of land may occur as a result of a bank failure or where steep creek banks within park areas pose a safety threat to the public. Approximately 1,130 active erosion sites have been cataloged in WPD's erosion database. However, despite over 14 years of implementation of stream stabilization projects, the number of erosion problems continues to increase due to two factors. First, stream systems are dynamic and continue to change and erode—it can take many years for the impacts of uncontrolled urban runoff to be fully seen. Second, staff continue to identify additional problems in new areas on smaller tributaries, where many of the more severe erosion problems are located.

Figure EX-5 Erosion threatens property on Fort Branch

Erosion problem scores are calculated with technical assessment data for individual sites and for stream reaches identified in the assessments.

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The resulting scores are used to prioritize erosion concerns across Austin. Table 6.7-2 in Section 6 presents the Top 20 ranked reaches by erosion problem score. Unsurprisingly, the highest (worst) problem severity scores are found in the urban core, where the majority of development occurred prior to the advent of Austin's protective watershed regulations. A relatively high percentage of the erosion reach score total is located in long-developed watersheds such as Shoal, Waller, Boggy, and Williamson Creek.

Water Quality Protection

The WPD goal for Water Quality Protection is to protect and improve Austin's waterways and aquifers for citizen use and the support of aquatic life. Exemplary surface and groundwater quality has always been and continues to be central to Austin's identity and well-being. Clear, flowing water is vital to human and ecological health, property values, and tourism. Since at least the early 1970s, Austin recognized that uncontrolled urbanization threatens water quality and, with it, these invaluable community resources: our lakes, rivers, creeks, and springs. Sources of water quality problems are numerous and complex to study and control. Key concerns include increases in runoff, sediment, nutrients, metals, litter, bacteria, and degradation of aquatic and riparian habitat.

Figure EX-6 Barton Springs Pool

To assess this complexity, WPD developed its Environmental Integrity Index (EII) monitoring and scoring system to compare a range of conditions across Austin's watersheds. A total of 118 reaches in 49 watersheds are currently sampled across Austin for the EII. While the EII remains the overall indicator of watershed ecological integrity, 10 individual problem scores derived from EII subcomponents are used to prioritize capital projects for the set of existing, feasible solutions used to address water quality problems in Austin:

1. Toxins in sediment
2. Litter
3. Bacteria from animals
4. Sewage
5. Nutrients (non-sewage)
6. Construction runoff
7. Poor riparian vegetation
8. Unstable channels
9. Altered hydrology: current
10. Altered hydrology: future

In addition, stream reaches in need of vegetative and soil restoration are also tracked and prioritized. Scores for each of the preceding 10 categories, plus the CIP and riparian zone restoration scores, are individually compiled to prioritize water quality concerns across Austin. As with flood and erosion, the highest (worst) problem severity scores tend to be found in the urban core, where the majority of development occurred prior to the advent of Austin's protective watershed regulations. Table 7.4-2 presents the Top 20 EII reaches by water quality CIP problem score.

Inventory of Potential Solutions

Section 9 presents an extensive inventory of over 150 available solutions to address the many watershed problems facing Austin. It gives descriptions, effectiveness, cost, and

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other implementation considerations for each solution. Solutions are grouped into capital, programmatic, and regulatory categories for the flood, erosion, and water quality missions, respectively. An additional **integrated** regulatory solutions category—those that address more than one mission—is also included. The three solution types are as follows:

- **Capital Projects** study, design, construct, and improve infrastructure and other capital-intensive assets. Examples include: storm drain systems; stream channel and riparian restoration; flood detention ponds; low water crossing upgrades; dam safety repairs; water quality controls; and buyouts of properties threatened by flood or erosion or to protect water quality.
- **Operating Programs** are a broad set of activities implemented by City staff. Examples include: infrastructure maintenance and inspections; engineering; planning and technical analysis; flood and water quality monitoring; spills response; and public education.
- **Regulations** are the legal framework to enforce City codes and rules. Examples include: peak flow and floodplain restrictions for flood control; drainage conveyance design requirements; erosion hazard protections; structural water quality controls; stream and sensitive environmental feature setbacks; impervious cover limits; control of illegal discharges; and drainage and environmental criteria to clarify how to comply with code requirements.

Identifying Preferred Solutions

Section 10 presents the screening protocol used to identify preferred solutions to address watershed problems. The protocol provides a framework to consider the nature and context of a given watershed problem; its potential solution types (capital, regulatory, or programmatic); the strengths, feasibility, and possible negative impacts of these solutions; and community considerations for the area in which the solution is proposed.

Solutions are measured by their effectiveness in achieving the watershed protection goals outlined in Section 2. Ideally, preferred solutions:

- Meet flood, erosion, and water quality goals and objectives;
- Maintain or improve the natural character of waterways;
- Minimize required maintenance;
- Ensure compliance with local, state, and federal regulatory requirements;
- Foster additional beneficial uses of waterways and drainage facilities where possible.

Solutions are also assessed for their ability to implement the vision, goals, and priorities of the Imagine Austin Comprehensive Plan. For example, the installation of rain gardens supports two Imagine Austin priority programs: sustainably manage our water resources and integrate nature into the city with green infrastructure. WPD helps lead implementation teams for both of these programs. Solution selection also takes into consideration the context of the problem. Austin's unique geography and history present different challenges (e.g., steep Hill Country topography vs. Blackland Prairie soils; existing urbanization vs. greenfields development; and water supply protection) which require different sets of solutions be tailored to address them (e.g., prevention vs. restoration). Potential targeted solutions are the subject of ongoing Watershed Profiles, included in Appendix C, which can focus on regional and local scales.

The WPD's **Mission Integration and Prioritization (MIP) Team** implements the solutions protocol process for capital improvement program (CIP)

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solutions. The MIP Team's mission is to identify cost-effective capital solutions to address watershed problems for all three departmental missions. Mission-integrated projects seek to:

1. Maximize solutions for the sponsoring mission (e.g., Flood Mitigation, Erosion Control, or Water Quality Protection);
2. Seek opportunities to attain goals of other WPD missions or City priorities (e.g., WPD common goals, other City departments' capital projects, Imagine Austin Comprehensive Plan goals, and Neighborhood Plan action items); and
3. Minimize negative impacts to all missions and City priorities.

Every year, MIP Team mission representatives use updated problem score data to identify "Top 20" Priority Problem Areas and potential capital project solutions for each mission. Figures EX-7 and EX-8, and Tables EX-2 through EX-6 show the latest Top 20 Priority Problem Areas. A detailed protocol is used to pinpoint preferred solutions. The MIP team then reviews each prospective project to maximize synergistic opportunities; minimize negative, unintended consequences; evaluate various alternatives for cost-effective solutions; and seek cost-sharing opportunities with other departments, agencies, and the private sector. The resulting, integrated capital projects are reviewed by WPD's Executive Team and, if approved, added to the WPD's five-year CIP appropriation plan for consideration for City Council approval.

Complementary, citywide efforts by the Capital Planning Office help identify and prioritize capital project needs that span multiple departments. The goal is to use City funding wisely, minimize disruption of services to the public, and ensure newly proposed projects implement the Imagine Austin Comprehensive Plan and address legal mandates, critical infrastructure needs, and other City policy initiatives (e.g., Neighborhood and Small-Area Plans).

WPD has made several estimates of the cost to implement capital solutions for identified watershed problems. These cost estimates range from $1.2 billion to $2.2 billion based on solutions developed for the 2001 Master Plan, as well as limited solutions identified in Phase 2 watershed studies. These estimates serve to provide a baseline, conservative estimate for total potential costs because information for all problem areas is not available. For example, solutions and costs to resolve local flooding problems are largely limited to areas of known flooding; they do not include the full cost of assets maintenance to address aging systems. And, even where solution information is available, most is based on preliminary investigations; further study is needed to refine the expected costs.

A new methodology for cost estimates is also being developed for the Water Quality Protection mission, based on the additional solutions types developed since the 2001 Master Plan to address Water Quality Protection goals. Efforts to provide revised costs for the Creek Flood and Erosion Control capital solutions are also underway. The Capital Planning Office is leading a citywide effort to identify asset management needs and associated cost estimates. The development of updated project costs for all missions, including asset management costs and evaluation for "level of service," is both a major undertaking and a priority to WPD; it will be available in a future Watershed Master Plan update.

Section 10 presents the WPD protocol for new and improved WPD operating programs. The 2001 Master Plan made recommendations for program enhancements and a limited number of new programs. The status of these enhancements is presented in Appendix D. With the exception of very few items, all enhancements from these original recommendations have been implemented or are underway, with some greatly exceeding expectations of the original recommendations.

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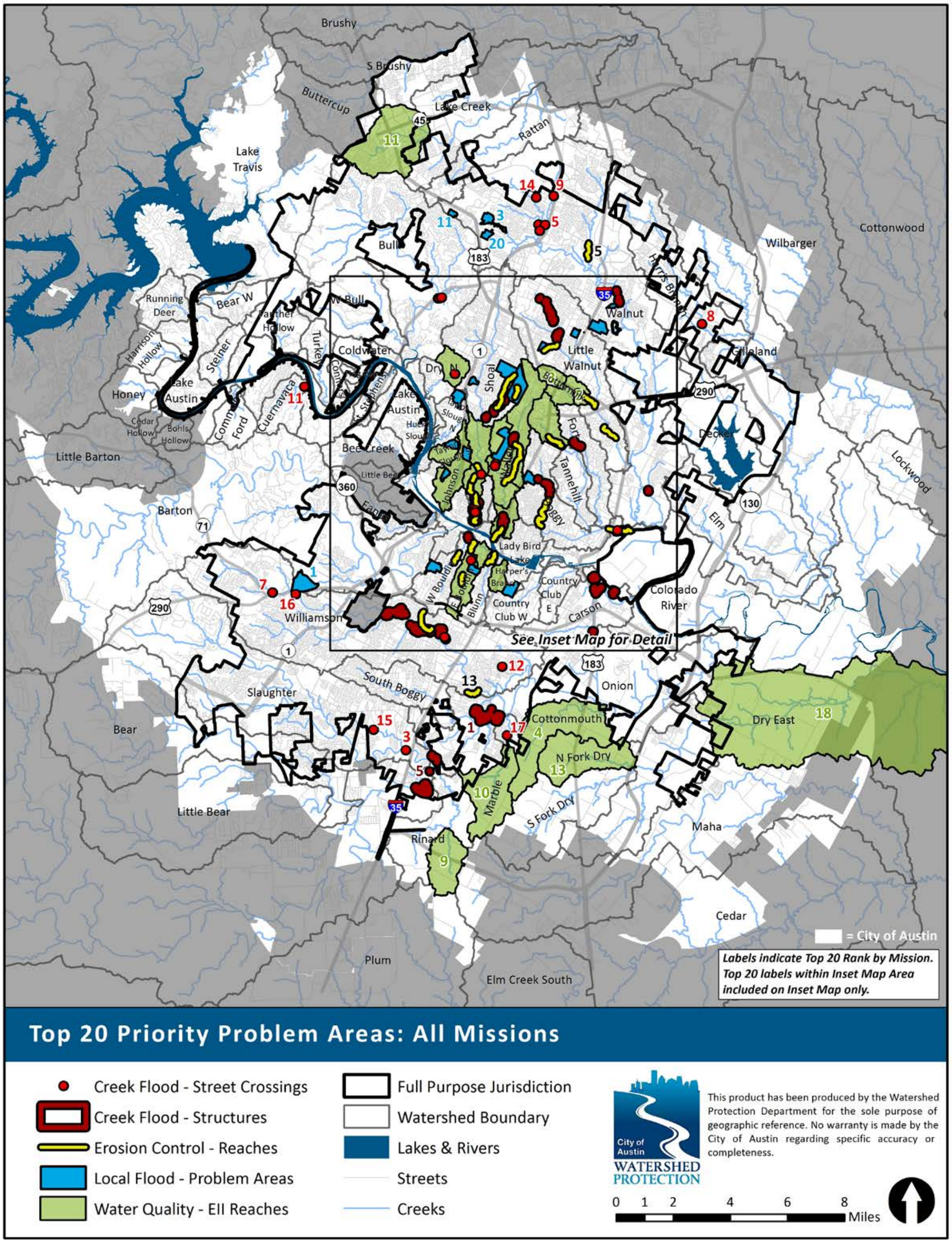

Figure EX-7 Top 20 Priority Problem Areas: All Missions (October 2015)

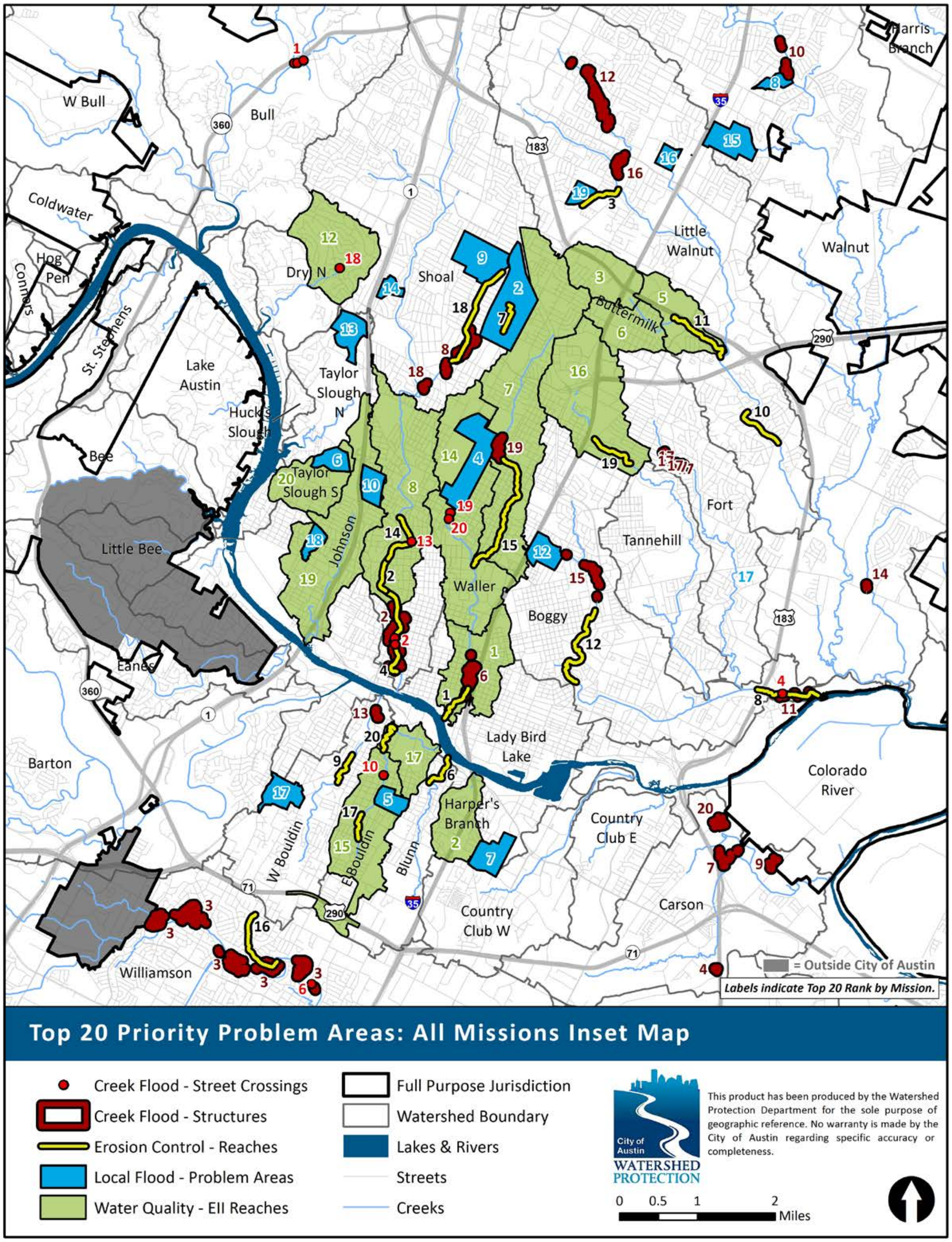

Figure EX-8 Top 20 Priority Problem Areas: All Missions Inset Map (October 2015)

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Table EX-2 Creek Flood Top 20 Priority Problem Areas - Structures (October 2015)

Creek Flood Top 20 Priority Problem Areas - Structures		
Rank	Watershed	Problem Area Description
1	Onion	Onion Creek Buyouts
2	Shoal	Lower Shoal Creek
3	Williamson	Cherry Creek to S Congress Ave
4	Carson	Metropolis Drive at US 183
5	Onion	Pinehurst Dr Subdivision & Wild Dunes
6	Waller	Waller Creek Tunnel
7	Carson	Bastrop Hwy and Patton Ave
8	Shoal	Shoal Creek at Hancock Tributary
9	Carson	Carson Creek at Dalton Ln
10	Walnut	February Dr and River Oaks Trail
11	Boggy	Shelton Rd at Delwau Ln
12	Little Walnut	Metric Blvd to Rutland Dr
13	West Bouldin	Barton Springs Rd at West Bouldin
14	Walnut	Walnut at FM 969
15	Boggy	E 38 1/2 St to E MLK Jr Blvd
16	Little Walnut	Upper Little Walnut at Quail Cove
17	Fort Branch	Berkman Dr to Waterbrook Dr
18	Shoal	Shoal Creek Blvd and 49th St
19	Waller	Speedway & 45th St
20	Carson	Thompson Lane Mobile Homes

Table EX-3 Creek Flood Top 20 Priority Problem Areas - Street Crossings (October 2015)

Creek Flood Top 20 Priority Problem Areas - Street Crossings		
Rank	Watershed	Problem Area Description
1	Bull	Old Spicewood Springs Rd at 360 (3 crossings)
2	Shoal	W 9th St, W 10th St east of N Lamar Blvd
3	Slaughter	Old San Antonio Rd west of S IH 35
4	Boggy	Delwau Ln east of Ed Bluestein Blvd
5	Walnut	Waters Park Rd, Adelphi Rd, ONeal Ln south of Parmer Ln
6	Williamson	Wasson Rd east of S Congress Ave
7	Williamson	Old Bee Caves Rd north of W US 290 Hwy east W SH 71
8	Harris Branch	Cameron Rd south of E Parmer Ln
9	Walnut	McNeil Dr east of Mopac Expy
10	East Bouldin	W Monroe St east of S 1st St
11	Cuernavaca	River Hills Rd south of N Cuernavaca Dr
12	Williamson	Nuckols Crossing Rd north of E Stassney Ln
13	Shoal	Shoal Creek Blvd at N Lamar Blvd
14	Walnut	Del Robles Dr west of N Mopac Expy, south of McNeil Dr
15	Slaughter	David Moore Dr south of W Slaughter Ln
16	Williamson	Joe Tanner Ln south of W US 290 Hwy
17	Marble	Colton Bluff Springs Rd south of E William Cannon Dr
18	Dry Creek North	Highland Pass north of FM 2222 Rd
19	Waller	W 32nd St east of Guadalupe St
20	Waller	Wheeler St east of Guadalupe St

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Table EX-4 Local Flood Top 20 Priority Problem Areas (October 2015)

Localized Flood Top 20 Priority Problem Areas		
Rank	**Watershed**	**Problem Area Description**
1	Barton	Oak Acres
2	Shoal	Brentwood St
3	Walnut	W Cow Path
4	Waller	Guadalupe St
5	East Bouldin	Annie St
6	Taylor Slough South	Warren St
7	Lady Bird Lake	Briar Hill Dr
8	Walnut	January Dr
9	Shoal	Madison Ave
10	Johnson	Oakmont Blvd
11	Walnut	Oak Knoll Dr
12	Boggy	Hollywood Ave/Group 21
13	Taylor Slough North	Hancock Dr
14	Shoal	Bullard Dr
15	Walnut	North Acres
16	Little Walnut	Oriole Dr
17	West Bouldin	Del Curto Rd
18	Johnson	Stamford Ln
19	Little Walnut	Jamestown Dr
20	Walnut	Natrona Dr

Table EX-5 Erosion Control Top 20 Priority Problem Areas (October 2015)

Erosion Control Top 20 Priority Problem Areas - Geomorphic Reaches		
Rank	**Watershed**	**Problem Area Description**
1	Waller	Confluence north to E 5th St
2	Shoal	Pease Park from MLK Blvd to W 25th St
3	Little Walnut	Jamestown Tributary from Thurmond St to Payton Gin Rd
4	Shoal	Pease Park from W 4th St to MLK Jr Blvd
5	Walnut	W Parmer Ln to Walnut Creek Park Rd
6	Blunn	Little Stacy Park to Confluence
7	Shoal	Grover Tributary along Grover Ave
8	Boggy	US 183 Hwy to Confluence
9	West Bouldin	Jewell St to W Johanna St
10	Little Walnut	Loyola Ln to Manor Rd
11	Buttermilk	US 290 to E Anderson Ln
12	Boggy	Rosewood Park
13	Williamson	Bitter Creek Tributary
14	Shoal	Pease Park from W 25th St to W 29th St
15	Waller	E 24th St to Avenue G
16	Williamson	Richmond Tributary
17	East Bouldin	Cumberland Rd to W Oltorf St
18	Shoal	Hancock Branch along Arroyo Seco
19	Tannehill Branch	West of Berkman Dr to Cameron Rd
20	East Bouldin	Columbus St to By-Pass Structure west of S 1st St

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Table EX-6 Water Quality Protection Top 20 Priority Problem Areas (October 2015)

Water Quality Top 20 Priority Problem Areas - EII Reaches		
Rank	**Watershed**	**Problem Area Description**
1	Waller	Waller Creek, EII Reach 1 (WLR1)
2	Harpers Branch	Harpers Branch, EII Reach 1 (HRP1)
3	Buttermilk Branch	Buttermilk Branch, EII Reach 3 (BMK3)
4	Cottonmouth	Cottonmouth Creek, EII Reach 1 (CTM1)
5	Buttermilk Branch	Buttermilk Branch, EII Reach 1 (BMK1)
6	Buttermilk Branch	Buttermilk Branch, EII Reach 2 (BMK2)
7	Waller	Waller Creek, EII Reach 3 (WLR3)
8	Shoal	Shoal Creek, EII Reach 2 (SHL2)
9	Rinard	Rinard Creek, EII Reach 3 (RIN3)
10	Marble	Marble Creek, EII Reach 2 (MAR2)
11	Lake Creek	Lake Creek, EII Reach 3 (LKC3)
12	Dry Creek North	Dry Creek North, EII Reach 2 (DRN2)
13	North Fork Dry	North Fork Dry Creek, EII Reach 1 (NFD1)
14	Waller	Waller Creek, EII Reach 2 (WLR2)
15	East Bouldin	East Bouldin Creek, EII Reach 2 (EBO2)
16	Tannehill Branch	Tannehill Branch, EII Reach 3 (TAN3)
17	East Bouldin	East Bouldin Creek, EII Reach 1 (EBO1)
18	Dry Creek East	Dry Creek East, EII Reach 1 (DRE1)
19	Johnson	Johnson Creek, EII Reach 1 (JOH1)
20	Taylor Slough South	Taylor Slough South, EII Reach 1 (TYS1)

Examples include the multiple watershed education campaigns undertaken beyond the Grow Green program recommendation from 2001, as well as new riparian restoration and Grow Zone programs. Updated program recommendations are summarized in Section 11; they are primarily based on interviews with staff and feedback from the Environmental Commission. These recommendations seek to raise WPD's level of service, improve program performance, address asset management needs, and keep pace with the rate of growth in Austin.

Section 10 also presents the WPD protocol for new and improved WPD regulations. As with the programmatic recommendations, essentially all regulatory enhancements from the 2001 Master Plan recommendations have been implemented. Appendix E presents the status of these recommendations. Key regulatory improvements include the Watershed Protection Ordinance (WPO) and Imagine Austin CodeNEXT. Phase 1 of the WPO was passed by City Council in 2013 and included new protections and provisions for headwaters streams, natural floodplains, erosion hazard zones, and trail integration with greenways. With the adoption of this ordinance, the vast majority of the regulatory recommendations from the 2001 Master Plan have been addressed. WPO Phase 2 focused on synergistic opportunities to improve watershed hydrology and enhance water conservation.

CodeNEXT is a major reworking of the City's Land Development Code, called for by the Imagine Austin Comprehensive Plan and led by the Planning and Zoning Department. In 2015, WPD led the Green Infrastructure Working Group, one of five CodeNEXT public working groups. The Green Infrastructure Working Group examined how we can achieve the Imagine Austin goals of integrating nature into the city, sustainably managing our water resources, and creating complete communities through revisions to our

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zoning and environment codes. The input from this stakeholder process is being incorporated into staff recommendations for CodeNEXT.

Section 10 also summarizes the creation and work of the Value Engineering Team and interdisciplinary teams for modeling, data management, and green stormwater infrastructure. Each of these focuses on cost savings and process improvements for WPD capital, programmatic, and/or regulatory solutions.

Recommendations

The Watershed Protection Master Plan presents individual and common goals for watershed protection. These goals, originally established in 2001, remain unmodified in this present update. They continue to be ambitious and aspirational: to resolve flood, erosion, and water quality problems at a very high level. Since 2001, substantial progress has been made in meeting these goals as shown in Table EX-7 for capital projects, with additional key gains made with programmatic and regulatory improvements.

Even with these achievements, many challenges remain. The 2001 Master Plan attempted to broadly quantify potential goal attainment for the cumulative benefits of capital, regulatory, and programmatic solutions. These estimates were acknowledged to be preliminary due to the conceptual nature of the capital solutions and the inherent difficulty in estimating a numeric benefit for many of the programmatic and regulatory solutions. Estimates were, of course, limited to the 17 watershed areas studied in Phase 1.

This present Master Plan update reviews these estimates and makes recommendations for potential next steps. With 14 additional years of direct implementation experience and a doubling of watersheds to study, estimation of goal attainment has evolved considerably. The bottom line is that potential solutions are theoretically possible for all creek flood, local flood, and erosion problems—but come at a significant financial and/or community cost. Solution implementation and goal attainment are thus limited by cost and community support, not by technical constraints. Solutions for water

Table EX-7 Capital Project Benefits by Mission (2001 - 2015)

Mission	Benefits*

Creek Flood	• Over 1,300 total structures with reduced creek flood risk †
	  • Over 500 structures with reduced flood risk via a structural solution
	  • Over 800 parcels removed from flood risk with property buyouts †
	• 10 low-water crossings upgraded

Local Flood	• Over 11 miles of pipe replaced • Over 350 structures with increased local flood protection
Erosion Control	• Over 4.6 miles of streambank protected • 29 parcels removed from erosion risk with nonstructural solution (property buyouts)
Water Quality Protection	• Over 1.5 million pounds of total suspended solids (TSS) removed per year • Over 7,000 acres land area treated by structural controls

** Estimates represent available data reported in the City's capital project reporting database and does not include benefit information for all completed projects since 2001. Efforts to append this data are underway and will be reported in future Master Plan updates.*

† These totals reflect property buyouts completed as of August 2016. All other data will be updated in the next annual update.

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quality problems present a more challenging prospect. Contributing factors include limited available land for water quality control retrofits, lack of regulatory control beyond Austin's jurisdiction (especially for the Barton Springs Zone, Lake Austin, and Lake Travis), and uncertainty about the degree to which structural solutions can achieve water quality goals.

Finally, in June 2015 the Austin City Council appointed a Flood Mitigation Task Force (FMTF) to "gather information and develop recommendations related to citywide and area flooding and its impacts to property, public safety, and City finances, with an emphasis on flood mitigation solutions and funding options." The 22-member group presented its recommendations in a Final Report to Council on May 19, 2016. This effort lent important new perspectives on the City's efforts to address flood mitigation, offering over 200 recommendations. Many of the recommendations specifically refer to and/or modify central concepts laid out by this Watershed Protection Master Plan. Going forward, WPD staff and the Environmental Commission will continue to identify ways to implement the core FMTF concepts to improve the City of Austin's efforts to provide flood mitigation and watershed protection.

Findings

1. Substantial progress has been made since 2001 in addressing flood, erosion, and water quality problems in accordance with the Master Plan goals. For example, over 1,300 structures have been removed from the floodplain, 11 miles of storm drain pipe replaced, 4.6 miles of stream channel stabilized, and over 7,000 acres of developed land treated by water quality structural controls, as presented above in Table EX-7.
2. Despite this considerable progress, flood, erosion, and water quality problems continue to be widespread, primarily due to development prior to Austin's protective watershed regulations. WPD must continue to find ways to cost-effectively address these needs and take corrective action to avoid even greater costs if this action is deferred.
3. The City of Austin is a dynamic and rapidly growing city. Since the original 2001 Watershed Protection Master Plan, Austin has grown from an estimated 669,000 residents to over 900,000 in 2015—an increase of over one-third. This growth has increased the City's urbanized footprint and drainage infrastructure, proportionately increasing the burden to maintain these assets and protect lives, property, and the environment.
4. Over the next 40 years, a range of $1.8 billion to $2.2 billion in capital funds are required to construct new or improved integrated watershed protection facilities including detention ponds, channel stabilization projects, and other flood, erosion, and water quality controls.
5. Additional resources and funding are needed to provide adequate levels of assets maintenance of Austin's drainage infrastructure; current rates of repair and replacement are not keeping pace with the growing deterioration of the system, and delays in such action only further increases eventual costs.
6. The 2013 Watershed Protection Ordinance addressed the majority of outstanding regulatory recommendations from the 2001 Master Plan. Several additional code and criteria changes are still recommended to address the need for improved on-site infiltration for baseflow, reuse of water for conservation, and to address flood concerns with redevelopment.
7. Attainment of Erosion Control and Flood Mitigation goals may be technically possible, but will require significant funding and community support; the 2016 Flood Mitigation Task Force's Final Report presented many constructive recommendations on this subject.
8. Water Quality Protection goals may not be attainable through implementation of solutions presently evaluated in the

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Master Plan. Limited regional retrofit opportunities in urbanized watersheds and inadequate regulatory controls in areas outside the City's jurisdiction are significant constraints.

9. The Imagine Austin Comprehensive Plan strongly supports watershed and environmental protection elements, including the Watershed Protection Master Plan. It presents specific priority programs to "integrate nature into the city" using green infrastructure and "sustainably manage our water resources."

Recommendations

1. Continue to develop long-range funding proposals to support solution implementation.
2. Continue to integrate watershed solutions to effectively promote watershed protection goals across all missions.
3. Continue adherence to the core Master Plan principle that the most severe problems should be considered first for solutions identification and implementation as funding becomes available.
4. Continue to partner with others to achieve watershed protection goals, address challenges across jurisdictional boundaries, and realize economies of scale. Partnerships include those with private development and land owners; federal, state, and local governments; including other City Departments (e.g., the Capital Planning Office); community groups; and concerned citizens.
5. Develop an asset management plan in coordination with the Capital Planning Office to identify an approach and funding mechanism to address the long-term maintenance of Austin's aging drainage infrastructure; include an evaluation of an appropriate level of service for drainage repairs and replacements to implement this approach.
6. Continue to use Master Plan results to assist in the development of proposed WPD budget increases to fund priority program enhancements.
7. Continue to involve stakeholders at a high level in the comment and review process for all proposed regulatory modifications using the model established by the Watershed Protection Ordinance.
8. Refine watershed protection goals based on continued public involvement and experience gained in Austin and from other communities. For example, continue the evaluation of and experimentation with green stormwater infrastructure solutions to attain water quality goals. Consider revisions to Water Quality Protection goals to reflect additional evaluation and feasibility of solution implementation.
9. Update the Master Plan on a regular basis, such as a five-year cycle, to ensure that up-to-date information is included; maintain the updated Master Plan document and interactive maps with problem scoring and solutions data on the web for public access.
10. Continue to expand Master Planning efforts in Phase 2 watersheds as funding allows, including the development of more site-specific analysis via Watershed Profiles.
11. Continue to support watershed and environmental protection elements in the CodeNEXT process to best implement the vision and goals of the Imagine Austin Comprehensive Plan.
12. Continue to seek ways to implement the recommendations of the 2016 Flood Mitigation Task Force's Final Report to cost-effectively improve public safety and property protection from flooding.

In order to keep current information on high priority needs, the Watershed Protection Master Plan will continue to be revised to reflect updated information. These updates will include updates to problem scores for additional Phase 2 watersheds, results of improved modeling efforts, and current watershed conditions. An annual update regarding the plan's implementation status is provided to the

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Environmental Commission, which serves in an advisory capacity for the Watershed Protection Master Plan.

Environmental Integrity Index (EII) scores are now available for all watersheds wholly or partially within Austin's jurisdiction. Flood and erosion technical studies have been completed for many Phase 2 watersheds, as reflected in the updated problem scores in Sections 4 and 6. Additional studies of the Phase 2 watersheds will continue as funding is available.

WPD will continue to work with the public in developing sustainable watershed solutions for all watersheds in the City of Austin.

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Section 1

1 Introduction

1.1 Background

For more than three decades, the City of Austin has been recognized as a national leader in watershed protection. Beginning in the 1970s, Austin began to place an emphasis on creek protection and the prevention of future problems through regulation. In 1974, the Waterway Ordinance limited development in the 25-year floodplain, required developments to identify appropriate sedimentation and erosion controls, and brought a new focus to protecting the "natural and traditional character" of local creeks. Since that time, the City has enacted additional watershed regulations and established design criteria manuals aimed at mitigating increased runoff rates and pollutant loadings from new land development.

Th two most important events that helped shape the City's current watershed protection program were uncontrolled development in the late 1970s and the Memorial Day Flood of 1981. In the late 1970s, sediment from widespread construction visibly entered Lake Austin (our water supply) and Barton Creek, a beloved community swimming and hiking area. The Barton Creek activities were observed to have an immediate response in nearby Barton Springs. Public concern led to calls for improved water quality and erosion controls for development. The first water quality ordinance, which also called for the first construction-phase erosion controls, was passed with the Lake Austin Ordinance (1978). Provisions for stronger measures were expressly included in the Austin Tomorrow Comprehensive Plan of 1979, which in turn laid the groundwork for subsequent ordinances, such as the Barton Creek Ordinance (1980), Williamson Creek Ordinance (1980), and later, the Comprehensive Watershed Ordinance (1986), Urban Watersheds Ordinance (1991), and Save Our Springs Initiative (1992) (Swearingen, 2008).

Around the same time, the Memorial Day Flood of 1981 grimly underscored Austin's geographic location in what is known as America's "Flash Flood Alley"—an area of unusually intense flooding events. In response to the storm's devastating effects, the City implemented a new Drainage Fee to provide funding for an expanded stormwater management program. Between 1981 and 1984, strong public support for flood and

Figure 4.1-1 Memorial Day flood on Shoal Creek (1981)

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erosion bond packages became evident as voters authorized more than $75 million for capital improvement projects. The first ordinance that limited development in the 100-year floodplain was passed in 1983.

Thus, from the late 1970s to today, the City's flood, erosion, and water quality efforts have emerged and matured as a result of Drainage Charge funding, the passage of notable ordinances, and the development of supporting technical criteria, the Drainage and Environmental Criteria Manuals. These core regulations served to help prevent the creation of new problems, saving Austin's citizens countless repair and restoration costs and great damage to its creeks, aquifers, lakes, and the Colorado River. And the flood regulations prevented more lives from being placed at risk as Austin's population and land area have more than doubled since the flood protection ordinances from the 70s and 80s. But a great deal of development predated this period of preventative regulation—and some of the early regulations needed strengthening. Much of the City's current watershed protection efforts must necessarily target the repair of problems caused by longstanding, unregulated development; the work continues to improve these historic ordinances and integrate the best science learned since those times.

Today, the City's watershed management program has three primary missions: Flood Mitigation, Erosion Control, and Water Quality Protection. The programs that comprise these missions are described below:

Flood Mitigation

The City's Flood Mitigation mission seeks to be a national leader in comprehensive flood prevention, protection, and response. Mission elements to address "creek flooding" along major waterways and tributaries include: regulations for peak flow control and other flood management considerations, detention pond retrofits, improvements to low-water crossings, flood walls, channel widening, buyouts of homes most at risk of flooding, and dam safety inspections and repair. Program elements to address "local flooding" in smaller ditches and drainage pipes (before stormwater runoff reaches a larger creek) include: evaluation of existing storm drainage infrastructure, identification of flooding issues, investigation of reported flooding, as well as the design and construction of improvements. WPD works to evaluate the condition and coordinate the maintenance of existing infrastructure.

Erosion Control

The City's current Erosion Control program—now known as the Stream Restoration program—was formally adopted in 1991, during the formation of the Drainage Utility. The Stream Restoration program's objective is to create a stable stream system that decreases property loss from erosion and increases the beneficial uses of Austin's waterways. The program utilizes stream stabilization techniques such as reinforced earth bank reconstruction, limestone rock grade controls to stabilize

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the channel slope, and rock weirs to capture sediments and redirect flows. Native materials and vegetation are used to the greatest extent possible to enhance the natural creek setting.

Water Quality Protection

Austin has a multi-faceted stormwater quality program to manage pollution from urban areas. The City's control strategy relies on source control and treatment facilities to remove pollution. Source control measures include land-use zoning, impervious cover limits, creek and sensitive feature setbacks for new development, control of illegal discharges, public education, a spill and environmental complaint response program, and drainage facility maintenance. Structural controls and other corrective measures are also needed to protect water quality. The City pioneered the use of sand filtration systems. Today the types of treatment technologies have expanded to include wet ponds, retention/irrigation systems, and green stormwater options such as rain gardens, biofiltration, rainwater harvesting, and porous pavement. Other corrective activities include riparian zone restoration, control of invasive species, and management for endangered aquatic species. Other Water Quality Protection program activities include comprehensive collection, modeling, and evaluation of surface water and groundwater to track current conditions and predict future trends.

1.2 Need for a Master Plan

In 1982, Austin instituted its first drainage fee. Between 1982 and 1991, any monies raised by this fee could be used for stormwater management, but were not dedicated exclusively to stormwater projects. In 1991, the City established a Drainage Utility to oversee stormwater management programs and to ensure that funds raised by the fee would be used only for stormwater management and watershed protection programs.

The Watershed Protection Department (WPD) was created in 1996 with the merging of the flood and erosion programs from Public Works with the water quality protection programs of the Environmental and Conservation Services Department (ECSD). With the creation of this unified department, a new emphasis was placed on:

1) Improving the prioritization of future watershed protection efforts;
2) Determining the adequacy of existing funding levels; and
3) Integrating the three missions of the new department to more cost-effectively achieve Flood Mitigation, Erosion Control, and Water Quality Protection goals.

Shortly after the WPD was created, the Watershed Protection Phase 1 Master Plan was initiated to obtain citywide technical data on the Flood Mitigation, Erosion Control, and Water Quality Protection missions that is needed to prioritize watershed protection efforts. As solutions were developed and evaluated, they were analyzed to determine the most effective solution types for each problem

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area. The first Watershed Protection Master Plan was completed and approved by City Council in 2001. This update to the original 2001 Master Plan includes the many improvements, additions, and changes to the Watershed Protection Department's capital, operating, and regulatory work since 2001.

1.3 Master Plan Approach

The Master Plan sets forth a plan to protect watersheds, people, and property. The original 2001 Master Plan for the 17 Phase 1 watersheds included all twelve Urban watersheds, and five surrounding Suburban and Drinking Water Supply watersheds: Barton, Blunn, Boggy, Buttermilk, Bull, Country Club,[1] East Bouldin, Fort Branch, Harpers Branch, Johnson, Little Walnut, Shoal, Tannehill Branch, Waller, Walnut, West Bouldin, and Williamson Creek. The present Master Plan also includes additional Phase 2 watersheds. Phase 1 and 2 watersheds are shown in Figure 1.3-1. There are 49 watersheds in which technical data exists, with additional areas under review for potential future evaluation.

The first steps in developing this Master Plan were to establish the department mission and management goals. Section 2 of this report provides details on the goal-setting process. Next, technical assessments are performed to identify creek flood, local flood, erosion, and water quality problems. Technical assessments have been completed for all Phase 1 watersheds. Phase 2 watershed assessments are available for water quality (49 watersheds); creek flooding (30 watersheds); and erosion (26 watersheds, plus some additional creek reaches). Citizen complaint data and limited technical modeling assessments are available for local flood systems.

[1] Country Club Creek is now recognized as two separate creeks—East and West Country Club Creeks, split by a diversion channel. Thus the original 17 Phase 1 watersheds are now technically 18 watersheds.

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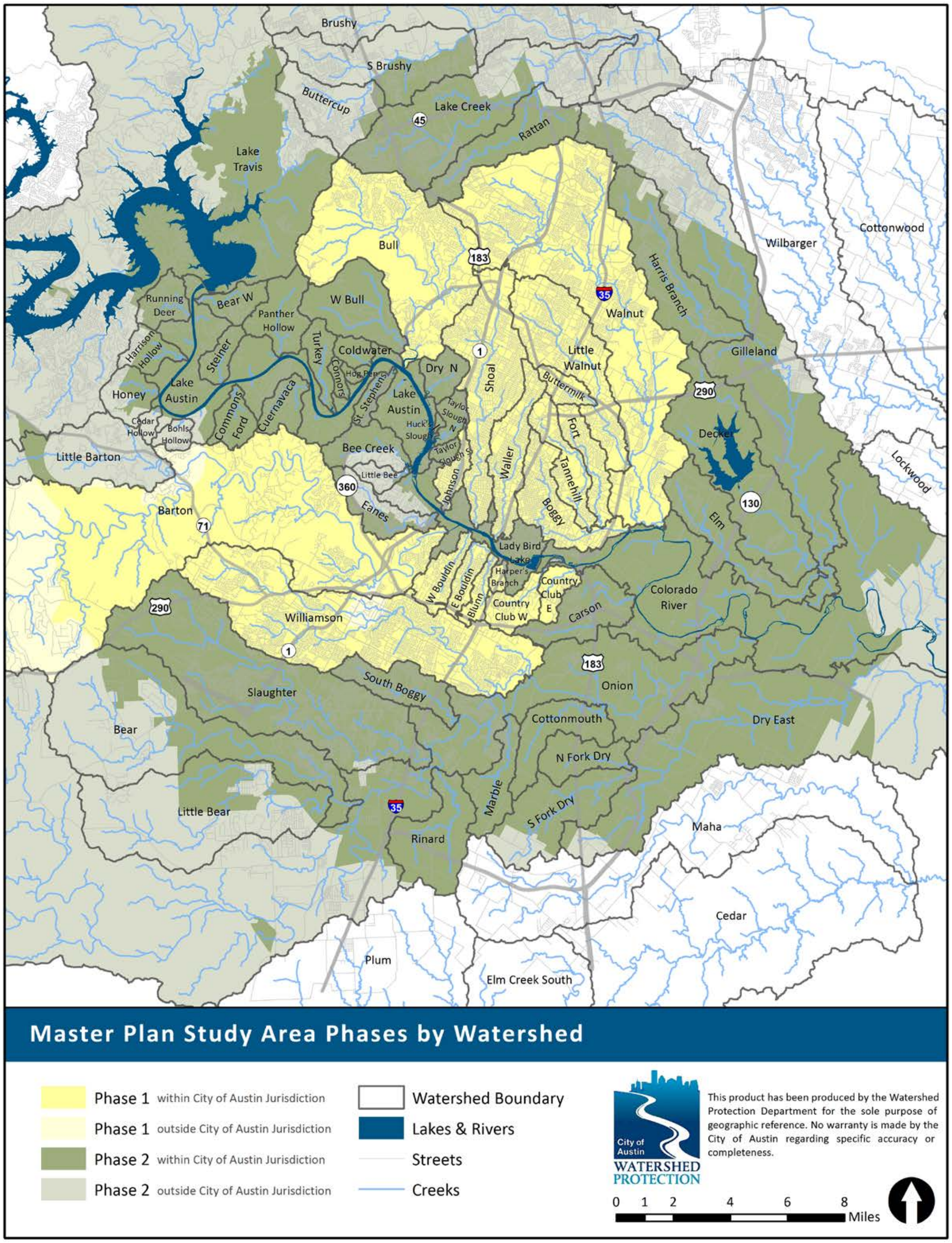

Figure 1.3-1 Master Plan Study Area Phases by Watershed

These technical assessments and approaches enable the identification and prioritization of "Problem Areas" for potential correction or restoration. Section 3 gives an overview of the problem identification and prioritization process. Sections 4, 5, 6, and 7 present more detailed information for Creek Flood, Local Flood, Erosion Control, and Water Quality Protection, respectively. In each section, all Problem Areas are quantified such that each may be ranked and prioritized against the others.

A central principle of this Master Plan is that the most severe problems should be considered first for solutions identification. This plan therefore outlines a "needs-based" prioritization approach using best available technical data. (At later stages of evaluation, additional factors, such as solution feasibility, timing, and opportunity to share resources, are also considered. See Figure 1.3-2 below.)

Some problem areas for one mission overlap with those of one or more of the other watershed missions. With all potential corrective actions, impacts to other missions need to be considered to ensure best use of resources and, at a minimum, no harm is done to another mission in solving a problem for another.

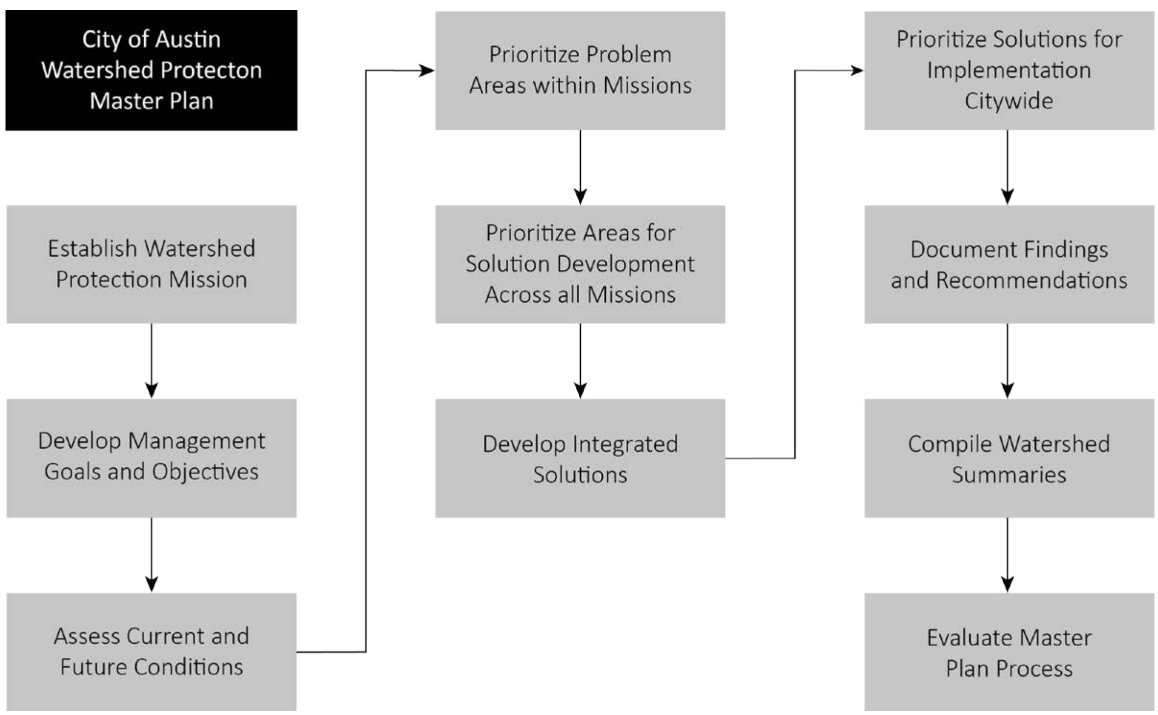

Figure 1.3-2 Master Plan Process

Once technical assessments provide prioritized problem data, solution identification begins. Section 9 presents an inventory of solutions available to address problems in the Flood Mitigation, Erosion Control, and Water Quality Protection missions. The section is divided to present three types of solutions: capital projects, operating programs, and regulations. Section 10 presents a series of "protocols" used by WPD staff to identify best potential solutions for each mission for a given watershed problem. It describes the Mission Integration and Prioritization (MIP) process and the

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system used to integrate best solutions for all missions in any given project. Section 11 concludes the report with a presentation of overall Master Plan recommendations and the priority implementation process.

1.4 Master Plan Public Input Process

In order to receive citizen input during the original Phase 1 Master Plan process, three major strategies were developed:

- Citizen's Advisory Group
- Public Input Survey
- Master Plan Public Meetings

1.4.1 Citizens Advisory Group

The Citizen's Advisory Group was formed early in the Master Plan process and consisted of members from varying interest groups and geographical areas throughout the city, representing neighborhood interests, water quality action groups, the academic community, as well as business and development interests. They provided advice on the process, made recommendations on various forms of public input, and promoted the Master Plan efforts among fellow citizens.

The Citizen's Advisory Group met throughout the development of the Phase 1 Master Plan. Once the plan was developed and the report was produced, periodic status reports on the implementation of the Master Plan recommendations were provided to the Environmental Commission. In 2008-09, when the first update to the Master Plan was initiated, a subcommittee of the Environmental Commission was appointed, at WPD's request, to provide continued public input into the Master Plan process.

1.4.2 Public Input Survey

The Watershed Protection Department commissioned an independent telephone survey in July 1997 to provide citizen input on drainage issues in their watershed. The 17 Phase 1 watersheds were divided into 39 polling areas based on the size of the watershed. Citizens were asked their level of concern about flooding, erosion, and water quality problems in their immediate neighborhood and in the City in general. They were also given the opportunity to describe any specific problem areas with which they were familiar. On the watershed level, results varied based on watershed specific concerns. The citywide survey results showed a nearly equal concern level for each of the missions, as seen in Table 1.4-1.

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Table 1.4-1 Public Input Survey Results

Mission	% of Respondents Expressing Concern
Flood Mitigation	35%
Erosion Control	30%
Water Quality Protection	35%

1.4.3 Master Plan Public Meetings

Three Phase 1 Watershed Protection Master Plan public meetings were held in 1998 to present information about watershed problem data and potential solution types. Citizens were encouraged to comment on these findings, as well as on the Master Plan process and utility funding. An additional meeting was held in 2001 to present the findings and solution recommendations of the Phase 1 Master Plan. The public meeting was co-sponsored by the Environmental Commission and the Citizen's Advisory Group.

1.5 Master Plan Public Process Today

Since the original Phase 1 Watershed Protection Master Plan, the WPD has sought to keep Austin's public aware of updates and changes in policies and work described in the Master Plan. WPD does this by (1) providing annual briefings to the Environmental Commission and (2) participating in planning outreach efforts.

The Citizen's Advisory Group was formed to oversee the 2001 Master Plan in coordination with the Environmental Commission. Once the plan was completed, the CAG dissolved and oversight reverted to the Environmental Commission. The Environmental Commission, appointed by Council, serves as the public oversight body for the Drainage Utility. WPD staff provide annual formal briefings to the Environmental Commission on the status of Master Plan implementation.

WPD also shares information on the Watershed Protection Master Plan in the City's various formal planning processes. These include the overarching Imagine Austin Comprehensive Plan as well as numerous "small area" neighborhood and corridor plans. These plans are developed by Planning and Zoning staff. WPD staff ensure that provisions of the Watershed Protection Master Plan are included and/or necessary components of the Imagine Austin Plan are updated. WPD staff attend public meetings, review citizen complaints regarding drainage problems, and provide input on Master Plan solutions that impact the affected planning area. Notably, the Imagine Austin Comprehensive Plan expressly acknowledges the Watershed Protection Master Plan: "Update the current Watershed Master Plan, expand the program to include other watersheds, and implement integrated strategies to protect and enhance water quality and supply, reduce flood risk, and prevent erosion" (Imagine Austin Comprehensive Plan, 2012, p. 192).

1.6 Master Plan Participants

The City of Austin managed the Watershed Protection Master Plan, utilizing consultants and researchers as needed to gather technical data on the problem areas and potential solution concepts. Table 1.6-1 outlines the efforts of the team members used on this project from the original 2001 Master Plan to the present.

Table 1.6-1 Master Plan Participants

Element	Participant
Erosion Assessments	Raymond Chan & Associates, PBS&J Inc., HDR Inc.
Flood Problem Assessment Hydrologic & Hydraulic model conversion	Loomis Austin Inc.
New Floodplain Studies	Halff Associates, Espey Consultants/RPS Espey, Watershed Concepts, HDR Inc., Raymond Chan and Associates, Atkins North America, Freese and Nichols
Flooded Structure Survey data	Carter & Burgess, City of Austin
Flooded Structure GIS application	City of Austin
Problem Area Prioritization System	City of Austin
Prioritization System Automation	Camp Dresser & McKee (CDM), ESRI, City of Austin
Pollutant Load GIS Modeling	University of Texas at Austin
Stream Erosion Solutions Development	Raymond Chan & Associates, Loomis Austin Inc.
Regulatory Solutions Development	Glenrose Engineering, Loomis Austin Inc, Raymond Chan & Associates, City of Austin
WPD Program Level of Service and Benchmarking	Loomis Austin Inc., Crespo Consulting, City of Austin
Initial Capital Solution Evaluation	Loomis Austin Inc.
Capital Solutions Protocols	City of Austin
Findings and Recommendations	City of Austin
General Technical Assistance and Report Reproduction	Camp Dressing & McKee, City of Austin

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Home Section 2

2 Watershed Protection Goals

Watershed protection goals define program direction, facilitate accountability, and thereby enhance public trust. A set of clearly defined and comprehensive watershed management goals is necessary to focus the Master Planning process. By including the public in the goal development process, consensus building and public trust are fostered as proposed management strategies are developed and measured against the desired outcome. This type of results-oriented, inclusive planning was a guiding principle for the Master Plan.

The following section provides an overview of the Watershed Protection Department (WPD) mission statement, management goals, and objectives. The goals and objectives were key factors in determining the type of data to be collected during the Master Plan to locate and describe watershed problem areas. Thus, they are reflected in the design of the technical assessments (field work and modeling) described later in Sections 3 through 8 of this Master Plan. In Section 10, the City's ability to achieve these goals is discussed.

2.1 Challenges of Watershed Protection

Changes to the landscape from urbanization can profoundly affect stream character. Urbanization in the form of impervious cover (rooftops, streets, sidewalks, driveways, and parking lots) represents that change. Increased impervious cover can alter the watershed's hydrology, increasing the risk of flooding and causing erosion. It also affects the quality of stormwater runoff, and initiates a chain of events that can degrade water quality.

2.1.1 Watershed Hydrology

Urbanization increases the amount of water that "runs off" into streams and causes flooding. Development sets in motion a series of hydrologic changes that:

- Increases peak discharges
- Increases stormwater runoff volume
- Reduces time needed for runoff to reach a stream, and
- Increases runoff velocity

These changes can lead to expansion of the floodplain and increased flood risks to people and property.

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To reduce the threat from flooding, the stream system is often modified to direct and convey runoff away from urbanized areas. Stream diversion, channelization, damming, and piping, which have been traditional responses to flooding and the altered hydrology of the stream, may degrade or displace stream beds and related aquatic habitats like wetlands. Conversely, the altered hydrology of the stream may reduce streamflow during prolonged periods of dry weather.

Stream channels change shape, or adjust, in response to more severe flooding caused by increases in impervious cover or urbanization. Higher flows may increase the size of a stream by widening stream banks, downcutting stream beds, or sometimes both. Stream channel instability, in turn, triggers a cycle of stream erosion. Property loss is a major expression of channel instability. Other consequences of stream erosion include the loss of aquatic habitat, such as a pool and riffle sequence, increased sediment deposition, and the loss of overhead protection and shading from the tree canopy.

2.1.2 Water Quality

Pollutant export increases dramatically both during and after construction. Site preparation practices such as clearing and grading leaves soils exposed and unprotected. Unless adequate erosion controls are installed and maintained at the site, sediment can be delivered to the stream channel, along with attached soil nutrients and organic matter.

Urban pollutant loads are directly related to watershed imperviousness. Impervious surfaces collect and accumulate non-point source pollutants deposited from the atmosphere, leaked from vehicles or derived from other sources. During storms, accumulated pollutants are quickly washed off and carried into local streams.

Major non-point source pollutants include certain types of bacteria, nutrients, toxic contaminants, debris, and sediment. Bacterial contamination indicates a possible health hazard and can affect drinking water and close recreational areas to swimming. Nutrients such as nitrogen and phosphorus “enrich” stream water leading to algae blooms that, when they subside, rob the water of oxygen, which fish and aquatic insects rely on. Toxic contaminants like heavy metals and pesticides threaten the health of aquatic organisms, which can also harm their human consumers. Furthermore, these contaminants may persist for a very long time. Debris is unsightly and in some cases harms animals and humans. Sediment, another non-point source pollutant, is a major concern because of its negative impacts to aquatic species and their habitats, and also because other pollutants can adhere to eroded soil particles.

2.2 Goal Setting Process

In early 1996, the newly formed Watershed Protection Department had its first opportunity to formulate integrated watershed protection goals. The “Planning for Performance” approach (Figure

2.2-1) adopted by the City heavily influenced the goal setting process. The first step in this planning process was to establish a mission statement for the WPD. The mission statement describes the purpose of the functional services performed by the WPD. This mission statement then leads to management goals that convey the vision and values of the community.

The goals that are established under a performance-based system should be a concise statement of the desired results of the City's watershed protection efforts. In other words, stated goals should convey long-term purpose and direction for the WPD. Typically, these goals do not change from year to year and are not quantifiable. For quantification purposes, objectives are developed that describe in specific, measurable terms the results a program is expected to achieve toward a certain goal. Objectives are commonly synonymous with the desired level of service. The stated objectives should be attainable within a certain timeframe and may change annually in an attempt to achieve the desired goal.

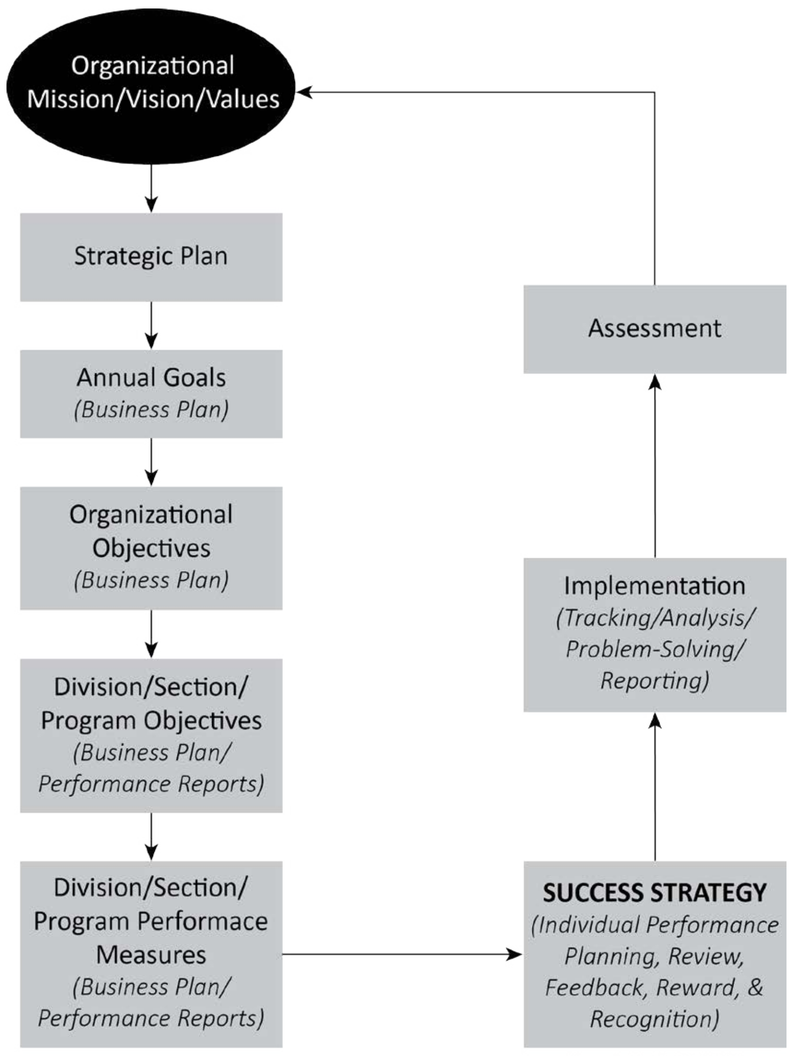

Figure 2.2-1 Planning for Performance Approach Flowchart

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Example:

Goal = To meet or exceed all TPDES [Texas Pollutant Discharge Elimination System] stormwater permit activities.

Objective = Comply with 123 activities specified in TPDES permit.

After establishing long-term goals and objectives, a strategic plan (e.g., this Master Plan) is developed to determine how best to achieve the stated goals. Long-term goals and objectives are translated into annual goals that are included in the WPD's business plans. Eventually, these annual goals help define the performance measures for the department's work groups and individual staff members through a performance review process. Finally, annual performance measures are tracked to relate the success of the strategic plan back to the original goals and objectives.

To promote consensus building and public understanding, WPD staff utilized several means for involving the community in the goal setting process. In the fall of 1996, three public meetings of the Master Plan Citizen Advisory Group (MPCAG) were dedicated to review and comment on the mission statement, management goals, and objectives. These goals were also reviewed in the three public meetings held during the spring of 1998 at local high schools to inform the public about the results of the technical assessment portion of the Master Plan. Goals are also presented in the WPD's business plan and annual budgets.

2.3 Mission Statement

As stated in the FY 2015-16 business plan, the current mission statement for the Watershed Protection Department is as follows:

The purpose of the Watershed Protection Department is to protect lives, property, and the environment of our community by reducing the impact of flooding, erosion, and water pollution.

Although the City has long realized that flood mitigation, erosion control, and water quality protection are integrally linked, an integrated mission statement for Austin's watershed protection efforts was created in 1995. Previous City budget documents and regulatory initiatives (e.g., 1974 Creek Ordinance) conveyed multi-objective goals, but none contained a concise mission statement that incorporated flood, erosion, and water quality concerns.

The origin of WPD's mission statement coincides with the inception of the primary funding mechanism for the City's current watershed protection activities: the Drainage Fee (now called the Drainage Charge). Created in 1982, the fee helped fund program activities of the Watershed Management Division (WMD) of the Department of Public Works and Engineering until 1986. At the time, WMD's established drainage program was complemented by a growing water quality section

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that provided monitoring, modeling, and design criteria/review support. Although WMD did not have an integrated mission statement, annual budgets included references to flood, erosion, and water quality objectives through 1986.

In FY 1986-87, the Water Quality Section of WMD was transferred to the newly created Department of Environmental Protection (DEP), thus separating the erosion and flood control activities from the water quality activities on an organizational basis. Not until 1990, when the City established a dedicated Drainage Fund, did the semblance of an integrated mission statement appear. In the enacting ordinance and amendments that followed, the declarations of purpose referenced a multi-objective theme:

> *"….in order to protect the citizenry from the degradation of water quality and loss of life and property caused by surface water runoff, overflows, and stagnation……it is necessary and in the best interest of public health and safety to a establish a drainage fee….(Ordinance No. 900913-Q)"*

In December 1993, a Drainage Utility Strategic Planning Team was formed that included City staff representatives of the erosion and flood mitigation mission groups (from the Public Works and Transportation Department) and the water quality management mission group (from the Environmental and Conservation Services Department, formerly DEP). The team's January 1995 final report contained the first integrated mission statement for the City's watershed protection efforts:

> *"The Mission of the Drainage Utility is to use environmentally-responsible and cost effective approaches to protect lives, property and the quality of life by managing the movement of water to reduce flooding, erosion and pollution."*

Based on staff review and public input, variations of this mission statement were created for the Master Plan and the WPD's annual business planning efforts. From 1995 until today, each version specifically addresses the three primary missions of the Watershed Protection Department: **Flood Mitigation**, **Erosion Control**, and **Water Quality Protection**. Ultimately, these missions reflect the City's commitment to improve public safety, property protection, and the quality of life in Austin.

For the most part, the information presented in this Master Plan is organized by these three missions. However, because the integration of these missions is a primary goal of this Master Plan, problem areas and solutions that address more than one mission are also presented.

2.4 WPD Goals and Objectives

Building on the department's mission statement, WPD developed seven management goals to guide the Master Plan in 1996. The long-term goals listed below reflect public input received during the goal setting process. The goals are further defined by multiple objectives (see Table 2.4-1). These goals and objectives are the same in the present Master Plan as were presented in 2001.

Table 2.4-1 Watershed Protection Department Master Plan: Goals and Objectives

GOALS	OBJECTIVES*
Protect lives and property by reducing the impact of flood events.	FM1. Reduce the depth and frequency of flooding for all 100-year floodplain structures. FM2. Reduce the depth and frequency of flooding on all roads in the 100-year floodplain. FM3. Reduce the danger at road crossings subject to any flooding by the 100-year flood (including provision of adequate warning at dangerous crossings). FM4. Provide mitigation for flood damage. FM5. Prevent the creation of future flood hazards to human life and property. FM6. Reduce the depth and frequency of local flooding for buildings. FM7. Reduce the depth and frequency of local flooding for yards. FM8. Reduce the danger of street flooding created by substandard storm drains. FM9. Reduce standing water in public rights-of-way and drainage easements outside the 100-year floodplain.
Protect channel integrity and prevent property damage resulting from erosion.	EC1. Repair current erosion that threatens habitable structures and roadways (referred to as Type 1 sites). EC2. Repair current erosion that threatens properties, trees, fences, drainage infrastructure, parks, hike and bike trails (Type 2 sites). EC3. Minimize the future enlargement of channels that would threaten public and private property (Type 3 sites). EC4. Achieve stable stream systems.
Protect and improve Austin's waterways and aquifers for citizen use and the support of aquatic life.	WQ1. In local creeks, achieve or exceed Good (≥ 62.6) Environmental Integrity Index (EII) scores. WQ2. In Urban creeks, restore baseflow quantity and quality to the maximum extent possible. WQ3. In Nonurban creeks, preserve the existing baseflow quantity and quality to the maximum extent possible. WQ4. In all creeks, reduce existing and future pollutant loads to the maximum extent possible. WQ5. In the Edward's Aquifer, maintain or enhance the existing rate of recharge to the maximum extent possible. WQ6. Maintain or enhance high quality environmental features (e.g., springs, seeps, wetlands, swimming holes, threatened or endangered species habitat) to the maximum extent possible.

**Primary Missions: FM = Flood Mitigation, EC = Erosion Control, WQ = Water Quality Protection, CG Common Goal*

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Table 2.4-1 continued

GOALS	OBJECTIVES*
Improve the urban environment by fostering additional beneficial uses of waterways and drainage facilities.	CG1. Maximize the use of waterways and drainage facilities for public recreation. CG2. Maximize areas for public use within floodplains. CG3. Maintain natural and traditional character of floodplains to the maximum extent possible.
Meet or exceed all local, state, and federal permit and regulatory requirements.	CG4. For all state designated stream segments, including Lake Travis, Lake Austin, Town Lake, the Colorado River below Austin, Barton, and Onion creeks, maintain or improve the Designated Use Support status. CG5. Comply with Stormwater NPDES permit requirements. CG6. Minimize risk to structures in the 100-year floodplain as required by the National Flood Insurance Program.
Maintain the integrity and function of Utility Assets.	CG7. Provide for adequate maintenance of the watershed protection infrastructure system and minimize maintenance requirements for system improvements.
Optimize City resources by integrating flood, erosion and water quality control measures.	CG8. Maximize flood control, pollution removal and streambank protection for all solutions including CIP projects.

**Primary Missions: FM = Flood Mitigation, EC = Erosion Control, WQ = Water Quality Protection, CG Common Goal*

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2.4.1 Flood Mitigation

The management goal of the Flood Mitigation (FM) mission is to protect lives and property by reducing the impact of flood events. This goal is further defined by the following objectives:

- FM1. Reduce the depth and frequency of flooding for all 100-year floodplain structures.
- FM2. Reduce the depth and frequency of flooding on all roads in the 100-year floodplain.
- FM3. Reduce the danger at road crossings subject to flooding by the 100-year flood.
- FM4. Provide mitigation for flood damage.
- FM5. Prevent the creation of future flood hazards to human life and property.
- FM6. Reduce the depth and frequency of local flooding for buildings.
- FM7. Reduce the depth and frequency of local flooding for yards.
- FM8. Reduce the danger of street flooding associated with old storm drains.
- FM9. Reduce standing water in public rights-of-way and drainage easements outside the 100-year floodplain.

Even in the midst of drought conditions, flash flooding poses a continuous threat to Central Texans. The heavy downpours common to this area combine with the steep slopes of the Balcones Escarpment to present an oftentimes dangerous combination for local motorists and creekside residents. These dangers are mostly present along flooded creeks, especially where bridges and low water crossing have been inundated with floodwaters. The allure of flooded streams can also be dangerous, as onlookers standing on soft and muddy banks can venture too close to the fast moving flows. In locations where old storm drain systems do not meet current criteria, rising waters can cause severe property damage even for those residents who do not live near flooded creeks.

The primary purpose of the Flood Mitigation mission is to reduce the existing and future impacts of flooding on local roadways and structures. This is true for both the primary creek system (creek flooding) and the local storm drain network (local flooding).

Creek flooding commonly poses the greatest threat to public safety. For this reason, an important activity of the Flood Mitigation mission is to issue flood warnings during heavy storms. Low water crossings are closed, and the public is encouraged to be attentive to any imminent flood danger. Flood insurance and floodplain information is also distributed on a routine basis to help mitigate property damage from floods and save lives.

Because heavy downpours occur infrequently, there is a tendency for the public to lose interest in flood management initiatives as past floods fade from memory. However, WPD's floodplain managers are actively planning and implementing solutions to improve the drainage system and reduce the creation of new flood hazards.

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Local flooding is the term given to flooding areas that result from the secondary drainage system (storm drains), not necessarily as a result of creekside flooding. Storm drains begin with inlets and include drain pipes, culverts, and open ditches. Local flood complaints occur more frequently than creekside flood complaints because they most often arise from smaller storm events. Local flooding problems can be categorized as building flooding, yard flooding, street flooding, or nuisance standing water.

Building or yard flooding can damage real property if stormwater runoff is not contained in the secondary drainage system. Often, the secondary drainage systems in the urban watersheds are outdated. Old or outdated storm drains mean storm drains designed and/or installed under drainage criteria in effect before January 1977. This is due to changes in design requirements over time. In fact, storm drains (namely, inlets and drain pipes) constructed before the 1970s appear to be sized for the 10-year (or less frequent) storm event. In certain areas where inlets and storm drains are outdated, the ponding of runoff along streets can result in undesirable driving hazards for motorists. The City has adopted stricter drainage requirements since the 1970s.

In addition to driving hazards, standing water in public rights-of-way and drainage easements poses a general nuisance related to diminished aesthetic value, mosquito breeding, soggy mud, pedestrian and vehicular inconvenience, and commonly foul odors. Standing water often appears as puddles or "bird baths" along minor ditches or deteriorated roadway infrastructure systems (curbs and gutters). Standing water can usually be attributed to poor design, poor construction, or poor maintenance. Sometimes, in flat or low areas, standing water cannot be completely eliminated by draining due to topographical constraints.

2.4.2 Erosion Control

The management goal of the Erosion Control (EC) mission is to prevent property damage resulting from erosion and protect channel integrity. This goal is further defined by the following objectives:

- EC1. Repair current erosion that threatens habitable structures and roadways.
- EC2. Repair current erosion that threatens properties, trees, fences, drainage infrastructure, parks, and hike and bike trails.
- EC3. Minimize the future enlargement of channels that would threaten public and private property.
- EC4. Achieve stable stream systems.

Urbanization alters the hydrologic response of a watershed to rainfall. Development increases the total volume, peak discharge rate, and frequency of runoff from rainfall events. Consequently, the capacity of urban streams and channels to withstand erosive flows is exceeded more frequently. The steep slopes in West Austin and the deep soils in East Austin exacerbate the erosive conditions

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caused by these higher runoff volumes and more frequent flow events, leading to unstable stream channels. Often, the result is severe channel erosion in the form of degradation and widening. Where structures have been constructed near stream banks, channel widening can pose a serious threat to property. Stream bank erosion also creates a significant sediment load to local creeks and lakes, resulting in increased turbidity and adverse impacts to aquatic ecosystems.

Historically, much of the City's Erosion Control program has been aimed at mitigating areas where stream bank erosion has posed an immediate threat to property (mostly homes and businesses) on a complaint basis. Without comprehensive erosion assessments that provide insight into the geomorphic characteristics of a creek (e.g., channel type, bank stability, and future enlargement potential), the preventive capabilities of the erosion program were severely limited. In 1997, Erosion Assessments for each of the Phase 1 watersheds were completed. These assessments were designed to evaluate the erosion conditions of each watershed compared to the erosion control goals and objectives described above. Therefore, each assessment includes an inventory of community resources threatened by erosion and an analysis of existing and future channel stability. This new Erosion Assessment data has enabled WPD to proactively plan for erosion mitigation and prevention and to promote geomorphically stable creek systems. This represents a tremendous advancement in the understanding of erosion control issues in our local creek systems. Please refer to Section 6 of this Master Plan for a detailed summary of the Erosion Assessment methods and results.

2.4.3 Water Quality Protection

The management goal of the Water Quality Protection (WQ) mission is to protect and improve Austin's waterways and aquifers for citizen use and the support of aquatic life. This goal is further defined by the following objectives:

- WQ1. In local creeks, achieve or exceed Good Environmental Integrity Index (EII) scores.
- WQ2. In Urban creeks, restore baseflow quantity and quality to the maximum extent possible.
- WQ3. In Nonurban creeks, preserve the existing baseflow quantity and quality to the maximum extent possible.
- WQ4. In all creeks, reduce existing and future pollutant loads to the maximum extent possible.
- WQ5. In the Edward's Aquifer, maintain or enhance the existing rate of recharge to the maximum extent possible.
- WQ6. Maintain or enhance high quality environmental features (e.g., springs, seeps, wetlands, swimming holes, and threatened or endangered species habitat) to the maximum extent possible.

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As natural lands are transformed into urban land uses, the increase in impervious area, traffic, and other human activity results in dramatic changes to local waterways. By altering the flow regime of creeks and increasing pollutant loads, urbanization can lead to adverse impacts to aquatic ecosystems and riparian areas. Some of these changes can be readily apparent as spills, trash, and debris create noticeable environmental problems. In other cases, changes in a waterway's environmental integrity occur very slowly in response to development. This is especially true of long-term erosive processes and gradual increases in pollutant loadings in slowly developing watersheds.

A common approach to water quality management is to focus on the reduction of non-point source pollution. While this has proven to be a valuable approach to stormwater quality management, this single measure does not adequately reflect the range of urban impacts on the beneficial uses of waterways. For example, reducing stormwater pollutants in runoff does not address the acceleration of streambank erosion and resulting loss of habitat quality due to increased storm flows.

One of the major objectives of the Water Quality Protection mission is to achieve or exceed "Good" Environmental Integrity Index (EII) scores for local creeks. The EII was developed by WPD as a tool to monitor and assess the ecological integrity and degree of impairment of local creeks and streams as they relate to beneficial uses. It represents a compilation of various sampling results that reflect the chemical, physical, and biological health of a stream system. The narrative results (discussed in Section 7) are reported in one of eight categories - Very Bad, Bad, Poor, Marginal, Fair, Good, Very Good, and Excellent. For creeks that meet or exceed the desired minimum score of "Good," a revised goal is established to attain a narrative score one level higher than the existing score in an effort to improve water quality citywide. Where creeks are found to be at the highest rating of "Excellent," the goal is to maintain this rating.

As a result of urbanization, much of the rainfall that once infiltrated into the ground and reappeared days later as creek baseflow now falls on rooftops and parking lots to be quickly conveyed to a ditch or storm drain. In addition to reductions in baseflow volumes, reduced infiltration of rainfall results in increased stormflows and a deficit of rainfall that is recharged to aquifers. Therefore, the Water Quality Protection mission strives to restore baseflow quantity and quality in urban creeks where the impacts of development are most prominent. In nonurban creeks, preservation of a watershed's baseflow characteristics is a high priority. Maintaining or enhancing recharge rates to the North and South (Barton Springs Segment) Edward's Aquifer helps promote baseflow and springflow volumes, protects aquatic ecosystems, and replenishes drinking water supplies. Likewise, the City promotes the protection of sensitive environmental features.

2.4.4 Common Goals

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Many of the goals of the Watershed Protection Department are common to each of the three missions described above. These shared goals cover a range of initiatives that strive to make the best use of City resources and maintain compliance with applicable state and federal regulations. Three common (CG) goals encompass a variety of objectives as follows:

Goal: Improve the urban environment by fostering additional beneficial uses of waterways and drainage facilities. This goal is further defined by the following objectives:

- CG1. Maximize the use of waterways and drainage facilities for public recreation.
- CG2. Maximize areas for public use within floodplains.
- CG3. Maintain natural and traditional character of floodplains to the maximum extent possible.

The City of Austin has a long history of promoting the public enjoyment of local waterways and constructed drainage facilities. Miles of greenbelts and hike and bike trails parallel Austin's creeks and lakes. Working closely with the City's Parks and Recreation Department, soccer fields and park areas are commonly integrated into the design of many Austin stormwater management facilities (e.g., Northwest Park and Dick Nichols Park). The effort to promote the public use of City drainage facilities and floodplains (while promoting the natural and traditional character of local creeks) will continue as new solutions are implemented in the future.

Goal: Meet or exceed all local, state, and federal permit and regulatory requirements. This goal is further defined by the following objectives:

- CG4. For all state designated stream segments, including Lake Travis, Lake Austin, Lady Bird Lake, the Colorado River below Austin, Barton, and Onion creeks, maintain or improve the Designated Use Support status (see State of Texas 30 TAC §307.10, Appendix A and D).
- CG5. Comply with Stormwater NPDES permit requirements.
- CG6. Minimize the risk to structures in the 100-year floodplain as required by the National Flood Insurance Program.

The City of Austin is obligated to comply with all applicable local, state, and federal permit and regulatory requirements. The objectives listed above are the three most prominent regulatory issues affecting the Watershed Protection Department. It should be noted that the WPD must comply with any state and federal permit or regulation that may be applicable to the daily operations of the WPD. In addition to the regulations addressed by the three objectives listed above, other applicable regulations commonly include the Texas Water Code, Local Government Code, and Federal Endangered Species Act.

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Mandated programs usually align with the City's designated goals. For example, the National Flood Insurance Program requires the City to minimize flood threats to structures in the 100-year floodplain, which is a stated goal of WPD's Flood Mitigation mission. In other cases, new permits and regulations create the need for new City initiatives. Routine dry weather screening is an example of a new water quality monitoring activity that is federally mandated through the City's NPDES stormwater permit. In most cases, noncompliance with state and federal regulatory requirements can lead to stiff penalties and fines. Therefore, it is in the City's best interest to ensure compliance is maintained on a continual basis.

<u>Goal</u>: Maintain the integrity and function of Drainage Utility assets. This goal is further defined by the following objective:

CG7. Provide for adequate maintenance of the watershed protection infrastructure system.

The City's drainage infrastructure system consists of hundreds of miles of creeks, improved channels, ditches, and storm drains. In addition, the system includes over 27,000 curb inlets and over 800 detention and water quality ponds. This extensive drainage network services over 260 square miles of the City. Providing adequate maintenance of the drainage infrastructure system is a high priority because:

1. The initial construction and improvements of this system represents a tremendous financial investment of both public and private resources, and
2. in order to achieve WPD goals (e.g., protection of lives, property, and the environment), the drainage system must function as designed.

Because the WPD operates as a public utility under the Texas Municipal Drainage Utility Systems Act, the components of the drainage system network are dedicated drainage utility assets. Therefore, from a financial perspective, it is the City's responsibility to maintain the value of its assets through a proper inspection, maintenance, and repair program.

From a goal attainment standpoint, maintaining the efficiency and effectiveness of the drainage system is imperative for the City to achieve its watershed protection goals. For example, the benefits of flood and water quality ponds can only be realized if these facilities are maintained properly. If debris is not cleared from clogged bridges after storms, subsequent storms could easily overtop the bridge, flood the immediate vicinity and erode adjacent streambanks. Each component of the drainage system must be operating as designed for the entire system to be effective.

<u>Goal</u>: Optimize City resources by integrating flood, erosion, and water quality control measures. This goal is further defined by the following objective:

CG8. Maximize flood control, pollution removal, and streambank protection for all solutions, including CIP projects.

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From the outset of the Master Plan, a high priority has been assigned to integrating WPD's three missions. The ability to reduce erosion and protect aquatic ecosystems is directly related to managing stormflow regimes. Water quality strategies must address streambank erosion concerns, and not inadvertently worsen flooding.

Through integration, resulting watershed protection strategies should ideally make the best use of drainage funds by simultaneously addressing flood, erosion, and water quality problems. While the opportunity to integrate missions is heavily influenced by site-specific factors (especially for capital projects), the selected approach should strive to improve the status quo for each mission. In some cases, maintaining the existing flood conditions may have to suffice for an erosion or water quality project. Likewise, a flooding project may not always incorporate water quality enhancement features. However, it should be noted that any new capital project should be designed to promote a sustainable and stable stream channel.

An integrated approach requires more thoughtful planning and sophisticated designs. Compared to a single-mission project, planning and design costs tend to be higher and project implementation periods tend to be lengthened as a greater variety of skilled planners and designers are involved in the process. However, when compared to the independent planning and design of separate flood, erosion, and water quality projects, the overall benefits of integration are tremendous.

To address this need of integration of capital solutions, an interdisciplinary team was formed to review all proposed capital solutions for integration elements and make annual recommendations on capital project appropriations. This team, the Mission Integration and Prioritization (MIP) Team, developed an integration process for all capital projects that must be completed. Mission integrated projects perform two primary functions: (1) maximize opportunities to reduce structure flooding, enhance the drainage system, maintain or improve channel stability, and maintain or improve the factors that affect water quality; and (2) minimize negative impacts to all missions. Because current watershed conditions are often below target levels or design criteria, opportunities to improve conditions, including project benefits, should be included which are beyond the need of the driving mission of the project. Additional detail on the project integration process is included in Section 10 of this report.

Public opinion and desires for capital projects can also impact the nature of a project design. Public sentiment regarding mission integration can vary widely based on the particular needs of a neighborhood and available funding.

It is the intent of this Master Plan to promote planning and implementation of integrated solutions to optimize the limited resources available to attain the WPD's diverse watershed protection goals.

Section 3

3 Problem Area Identification

The Watershed Protection Department (WPD) performs technical studies to characterize flood, erosion, and water quality problem areas for the watersheds within its jurisdiction. These studies help define watershed characteristics and locate areas within each watershed where watershed protection goals are not being achieved. This approach is designed to enable direct comparisons between watersheds and promotes consistency among the three missions.

This section introduces the methods used for data collection and evaluation to determine both current and projected future problems on a mission-by-mission basis. Sections 4, 5, 6, and 7 then detail problem area results for all watersheds for which information is available for Creek Flood, Local Flood, Erosion Control, and Water Quality Protection, respectively.[1]

3.1 The "Problem Score Approach"

Problem Score systems were developed to quantify and prioritize problem areas for each of the four department missions: Creek Flood (CF), Local Flood (LF), Erosion Control (EC), and Water Quality Protection (WQ). Problem scores assign a numeric value to watershed problems, such as individual erosion sites or structures in floodplains. These problem scores can in turn be aggregated into larger units, such as stream reaches, project groupings, or even entire watersheds, to enable comparisons across geographic areas.

Problem scores are adjusted (normalized) to range from 0 to 100: with a score of 0 reflecting ideal watershed conditions and a score of 100 representing the worst problem identified. The determination of a problem score for a given reach of a creek is a function of **problem severity**, the number of resources impacted, and the type of community resources impacted by the problem (reflected by the "**resource value**"). (Note: The Local Flood mission does not at present use a normalized scoring system; as more quantitative modeling information becomes available, such a system will be considered. See more discussion in Section 5.)

3.1.1 Problem Severity

Technical studies for each mission determine the severity of existing and potential future problems. For example, Creek Flood problem severity scores account for public safety and property protection

[1] The number of missions is sometimes given as four, when counting Creek Flood and Local Flood as two different entities.

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concerns for structures and low-water crossings using modeled flood depths for 2-, 10-, 25-, and 100-year storm events. The deeper and more frequent the predicted flooding, the higher the score (See Section 4 for further information). Local Flood problem severity scores are derived using citizen complaint data, with areas with the highest number and density of reported problems given the highest problem severity (See Section 5 for further information). Erosion Control problem severity scores quantify bank stability, vegetative cover or armoring, and stream planform (meander). Structure, infrastructure, and other resources in areas with steep slopes, high banks, poor vegetative cover, and/or on the outside of creek bends would be expected to have higher problem severity scores than those with the opposite (See Section 6). Water Quality Protection problem severity scores track numerous factors, such as bacteria, nutrients, and litter based on field sampling results. When available, additional scoring factors for future watershed conditions will be determined using predictive watershed models (See Section 7).

3.1.2 Resource Values

Numerical values are assigned to resources potentially threatened by flooding, erosion, or impaired water quality. These values were established with input from the Master Plan Citizens Advisory Group. The numeric scores are calculated slightly differently for each mission, for the resources affected and the values placed on each resource are different across the missions.[2] For example, resources threatened by flooding or erosion include homes and businesses, while resources impacted by poor water quality are individual creek segments, including the recreational value and aquatic life they support. Again, using a score between 0 and 100, high priority resources (e.g., a school or a hospital) may be given a resource value of 90 – 100, with lower values given to resources of lesser priority. Resource values established for each mission are presented in the discussions of mission-specific study methods later in Sections 4, 5, 6, and 7.

3.1.3 Problem Score Calculations

Problem scores are generated using a combination of the problem severity and the resource value. These scores can then be aggregated by stream reach, project area, or watershed as needed for a given scale of analysis. For example, the erosion problem score for a given reach is derived by combining the individual problem scores of each erosion problem site in the reach. The scores for these aggregated units are then normalized on a 100-point scale to simplify comparisons. Thus the worst erosion reach studied would have a score of 100. All other erosion reaches would have scores relative to this high score. Sections 4, 5, 6, and 7 all present more detailed discussions of these scores and summary information by watershed.

[2] A future Master Plan update will re-evaluate the differences between resource values.

Section 4

4 Creek Flooding Assessment

4.1 Background

The earliest recorded flood in Austin occurred in 1832 when, according to the Bicentennial record, the Colorado River rose more than 46 feet. This occurrence predates Austin being chartered as the capital of the Republic of Texas in 1839 and the Civil War. In nearly every decade since, there is a record of significant flood events. Most people who live in Austin have witnessed firsthand or seen reports of flooding of homes, roads, or other property.

Figure 4.1-1 Halloween Storm of 2013

The “big” storms of 1981, 1991, 1998, 2001, 2002, 2007, 2010, 2013, and 2015 are reminders of the public safety and property hazards associated with flooding. Hydrologists classify or “size” storms based upon how often they are likely to occur. For example, a very large storm that has a 1% probability of occurring in any given year is termed a 100-year storm event. The Memorial Day flood of 1981 killed 13 people and resulted in over $35 million in property damage; it was estimated to be approximately a 100-year storm for Shoal, Walnut, and Little Walnut watersheds (lesser frequency for other watersheds). Figure 4.1-1 depicts the Halloween Storm of 2013, which resulted in an estimated $44.6 million in property damage, damaged 858 homes, and killed 4 people in Travis County, was estimated to be between a 10-year and 300-year storm at various gauge locations throughout the Onion Creek watershed.

4.2 Overview of Assessment Methodology

Section 4 describes the methods used to investigate problems associated with the primary system (major creeks and their tributaries), termed “Creek Flooding.” The methodology takes citywide creek flooding information derived from hydrologic and hydraulic flood models, ranks problems by severity, and proposes a list of Top 20 problem areas. Solutions to these problems are discussed later in Section 10. Methods used to investigate “Local Flooding” associated with the secondary drainage system (storm drains and minor channels) are reviewed in Section 5.

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Figures 4.2-1 and 4.2-2 graphically present the methodology for structure flooding and roadway crossing flooding, respectively.

Structure Flooding Assessment Methodology

1. **Collect Data on All Structures.** All structure flooding locations along creeks in Austin's full purpose and extraterritorial/limited purposed jurisdictions are identified using flood models. Each structure is tracked in GIS and given numeric problem severity scores based on resource values and modeled flood frequency and depth. The higher the score, the more severe the problem.

2. **Generate Problem Scores.** Points are buffered in GIS based on severity score, then merged with intersecting buffers to create Structure Clusters. Clusters are re-scored by summing all individual structure scores within the cluster and normalized on a 100-point scale. Normalized scores are assigned a narrative rating of Very High to Very Low.

3. **Extract Full Purpose Problem Areas.** Clusters located in the extraterritorial and limited purpose jurisdictions are removed.[1] Remaining full purpose structure cluster scores are re-normalized to 100 and ranked. The highest-ranking clusters are reviewed manually to combine adjacent clusters that would be assessed together for regional solutions. Clusters are then re-scored, normalized, and ranked. The 20 highest scoring (ranking) clusters are identified.

4. **Prioritize Problems for CIP Solution Identification.** High ranking problem areas are further evaluated for site-specific feasibility considerations. Section 10 discusses how projects are developed and prioritized for priority problem areas.

[1] The removed clusters are retained in the data set because they need to be tracked for future annexation impacts, but are not considered for near-term solution identification and funding. Unless and until annexed, these problem areas are the responsibility of their respective county (e.g., Travis or Williamson Counties).

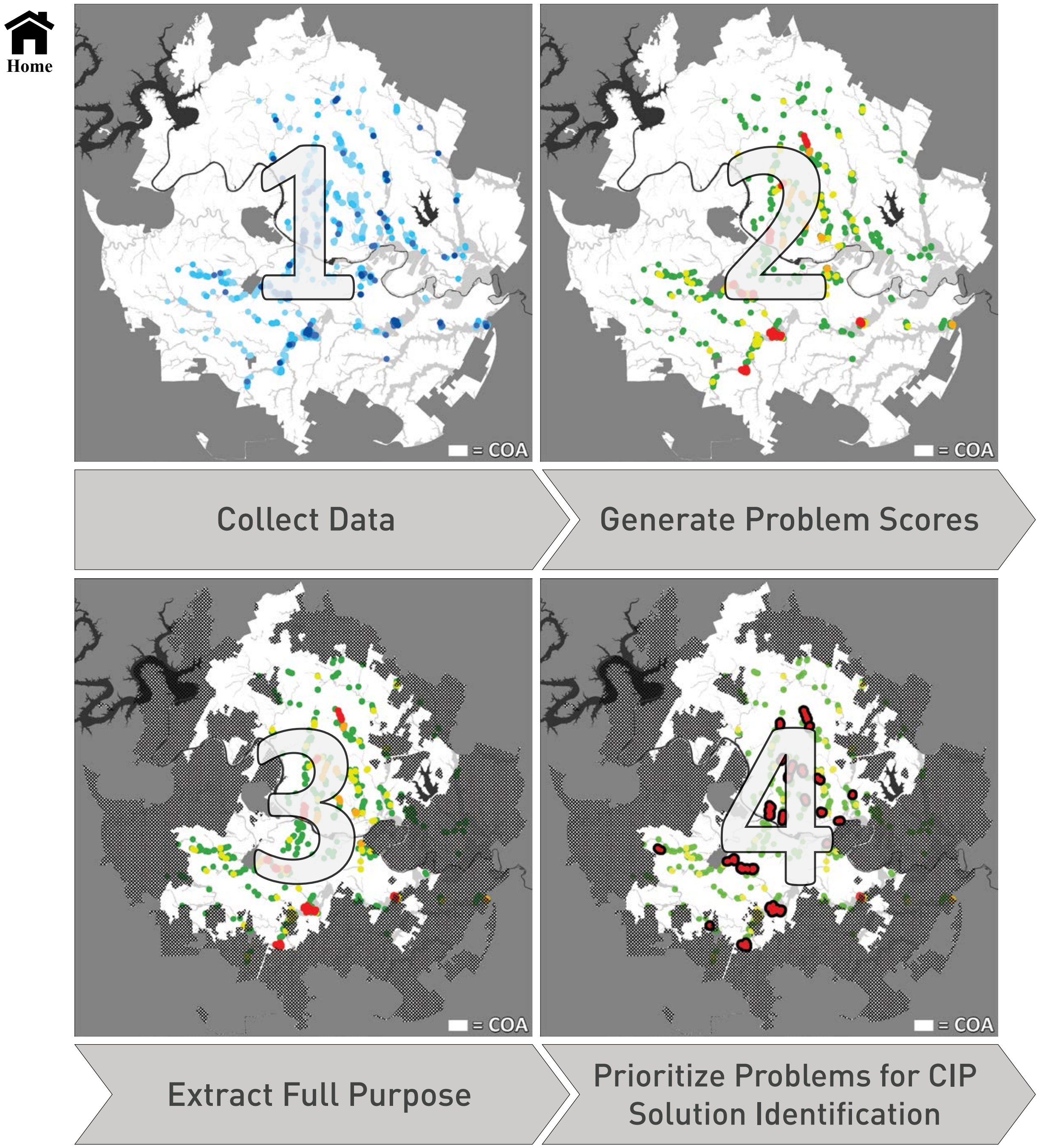

Figure 4.2-1 Creek Flood Structure Prioritization Methodology (2015). Steps 1 - 3 are described here in Section 4, while Step 4 is described in Section 10.

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Roadway Crossing Flooding Assessment Methodology

1. **Collect Data on All Crossings.** All street crossing locations in Austin's full purpose and extraterritorial/limited purposed jurisdictions are identified in GIS. Crossing points are assigned a resource value and modeled for flood frequency, depth, and velocity.

2. **Generate Problem Scores.** Crossing points are scored using a problem score methodology and normalized to 100. The higher the score, the more severe the problem. Normalized scores are assigned a narrative rating of Very High to Very Low.

3. **Extract Full Purpose Crossing Locations.** Crossings located in the extraterritorial and limited purpose jurisdictions are removed.[2] Remaining full purpose crossing locations are ranked. The 20 highest scoring (ranking) locations are identified.

4. **Prioritize Problems for CIP Solution Identification.** High ranking problem areas are further evaluated for site-specific feasibility considerations. Section 10 discusses how projects are developed and prioritized for priority problem areas.

[2] The removed clusters are retained in the data set, since they need to be tracked for future annexation impacts, but are not considered for near-term solution identification and funding. Unless and until annexed, these problem areas are the responsibility of their respective county (e.g., Travis or Williamson Counties).

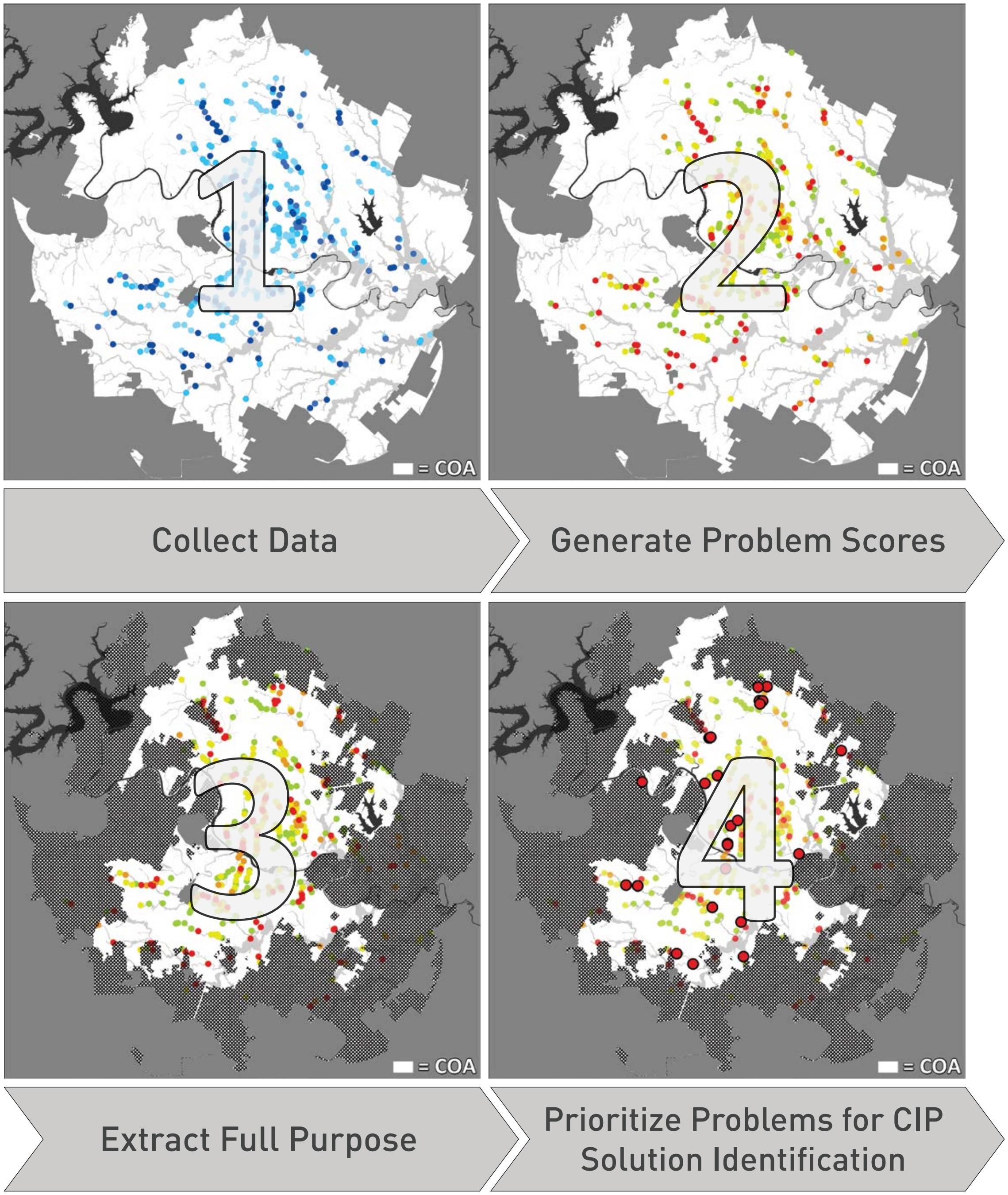

Figure 4.2-2 Creek Flood Road Crossing Prioritization Methodology (2015). Steps 1 - 3 are described here in Section 4, while Step 4 is described in Section 10.

4.3 Study Methods

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Flooding problems in major creek systems are identified with the aid of hydrologic and hydraulic (H&H) models. Hydrologic models use data describing watershed and channel characteristics to compute stormwater runoff quantities for design storms of various sizes (e.g., the 100-year, 24-hour event). Hydraulic models are then employed to predict the water surface elevation (WSEL) and velocity of flow in creek channels based on the flows computed by the hydrologic models. The predicted WSEL helps determine when creek levels will be high enough to overflow creek banks and flood nearby structures (e.g., bridges, culverts, homes, and other buildings). This analysis is performed for projected future fully developed land use conditions. For this Master Plan, floodplain models were used to estimate flooding resulting from the 2-, 10-, 25-, and 100-year storm events.

Over the past 35 years, the City has developed floodplain models and maps for almost all major City-managed watersheds. The City, local private engineering consultants, FEMA, and the U.S. Army Corps of Engineers (USACE) have been the primary developers and users of flood models for the major creek systems in Austin. As discussed in Section 3, the flood risk assessments performed for the Master Plan rely on watershed data provided by H&H models to support analysis of problem areas.

The 2001 Master Plan included creek flood data for all but two of the Phase 1 watersheds.[3] To date, flooding issues in these two Phase 1 watersheds (Barton Creek and Harpers Branch) have not warranted the prioritization of these watersheds for detailed floodplain studies;[4] Phase 2 watersheds with greater flooding problems were prioritized ahead of them. However, studies of these watersheds, along with several others, are planned between 2015 and 2020. This present Master Plan includes data for the previously modeled Phase 1 watersheds and 11 additional Phase 2 watersheds. H&H models maintained by LCRA are available for areas of direct drainage along Lake Austin, Lady Bird Lake, and the Colorado River below Longhorn Dam, but creek flood problem scores are not available for these areas. A summary of the availability of creek flood data for Austin's watersheds is shown in Table 4.3-1 and Figure 4.3-1, whereas Table 4.3-2 presents estimates of when data will become available for watersheds that have yet to be assessed.

[3] Country Club Creek is now recognized as two separate creeks—East and West Country Club Creeks, split by a diversion channel. Thus the original 17 Phase 1 watersheds are now technically 18 watersheds.
[4] The identification of significant problems on the Gaines Creek tributary of Barton Creek warranted a detailed flood study, but the rest of the Barton Creek watershed has not been modeled or scored (see Table 4.3-1 and Figure 4.3-1)

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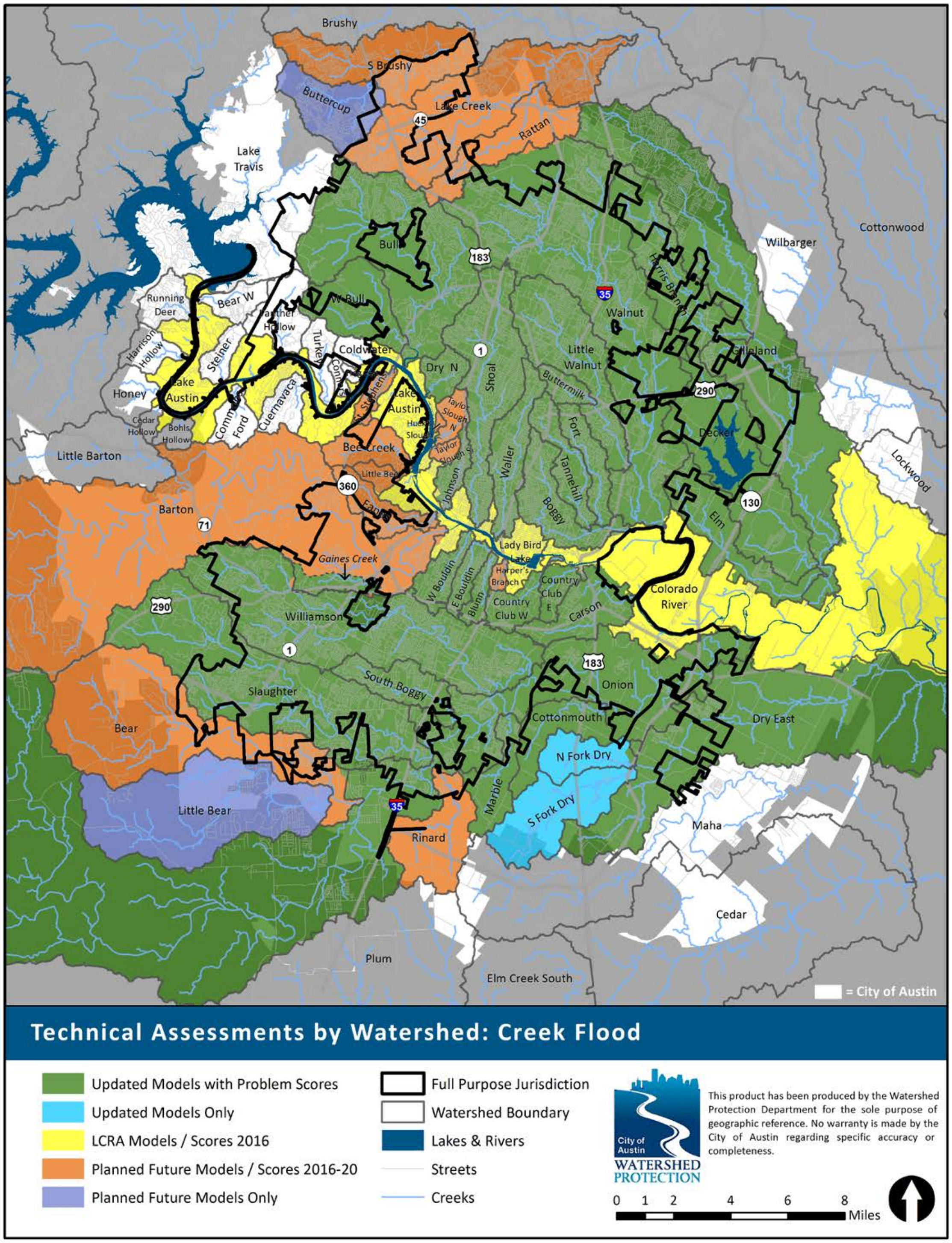

Figure 4.3-1 Map of Watersheds with Creek Flood Technical Assessments (2015). This map displays the status of detailed floodplain models and Master Plan problem score data. Problem score data is currently assessed for watersheds that intersect the City of Austin's full purpose jurisdiction.

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Table 4.3-1 Summary of Phase 1 and 2 Watersheds (2015)

Watershed		Phase	Updated Models Available?	Problem Scores Available?*
1.	Barton (Gaines)	1	yes	yes
2.	Blunn	1	yes	yes
3.	Boggy	1	yes	yes
4.	Bull	1	yes	yes
5.	Buttermilk	1	yes	yes
6.	Carson	2	yes	yes
7.	Colorado River	2	LCRA-maintained	2016
8.	Cottonmouth	2	yes	yes
9.	Country Club East	1	yes	yes
10.	Country Club West	1	yes	yes
11.	Decker	2	yes	yes
12.	Dry East	2	yes	yes
13.	Dry North	2	yes	yes
14.	East Bouldin	1	yes	yes
15.	Elm	2	yes	yes
16.	Fort Branch	1	yes	yes
17.	Gilleland	2	yes	yes
18.	Harris Branch	2	yes	yes
19.	Johnson	1	yes	yes
20.	Lady Bird Lake	2	LCRA-maintained	2016
21.	Lake Austin	2	LCRA-maintained	2016
22.	Little Walnut	1	yes	yes
23.	Marble	2	yes	yes
24.	Onion	2	yes	yes
25.	Shoal	1	yes	yes
26.	Slaughter	2	yes	yes
27.	South Boggy	2	yes	yes
28.	Tannehill Branch	1	yes	yes
29.	Waller	1	yes	yes
30.	Walnut	1	yes	yes
31.	West Bouldin	1	yes	yes
32.	West Bull	2	yes	yes
33.	Williamson	1	yes	yes

**If no problem score is available, the estimated year of update entered.*

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Table 4.3-2 Future Floodplain Models (2015)

Watershed		Phase	Estimated Model Availability	Estimated Problem Score Availability
1.	Eanes	2	2015	2016
2.	Harpers Branch	1	2015	2016
3.	Rinard	2	2015	2016
4.	Hucks Slough	2	2017	2018
5.	Taylor Slough North	2	2017	2018
6.	Taylor Slough South	2	2017	2018
7.	Barton (All Reaches)	1	2019	2020
8.	Bee	2	2020	2021
9.	Little Bee	2	2020	2021
10.	St. Stephens	2	2020	2021
11.	Bear	2	2015 - 2020	2016 - 2021
12.	Buttercup	2	2015 - 2020	-
13.	Lake	2	2015 - 2020	2016 - 2021
14.	Little Bear	2	2015 - 2020	-
15.	Rattan	2	2015 - 2020	2016 - 2021
16.	South Brushy	2	2015 - 2020	2016 - 2021

In October 2003, FEMA Region VI selected Travis County as one of the first ten counties for its nationwide Floodplain Map Modernization Project. The City of Austin actively participated in the project, contributing funding for additional detailed watershed studies and adding analysis of fully developed land use conditions. As a result, 22 City-maintained watersheds (including 14 Phase 1 watersheds) were modeled with detailed study methods, new systematic cross-section survey data, more accurate topographic, land-use, soil, and ground surface roughness data, and the latest H&H modeling and GIS mapping technology. Subsequently, the City completed new studies for eight watersheds (Gilleland, Decker, Elm, Dry East, Cottonmouth, Tannehill Branch, Bull, and West Bull) and restudies for four watersheds (Shoal, Boggy, Fort Branch, and Carson) using the latest GIS technology. All new floodplain models incorporate both the existing and the projected fully developed land use conditions.

Once models are developed to estimate the water surface elevation for flooding for the four design storms, the next step in the flood assessment methodology is to identify all flooded structures and determine the resulting severity of flooding at specific points of interest for future land use development conditions. These points include residential and commercial buildings, low water crossings, and bridges. In order to accomplish this task, additional information regarding structure location and finished floor elevation is needed. Structure locations are identified with the City of Austin building footprint layer. Finished floor elevations are assigned to each building at the centroid of the footprint based on 2012 LIDAR data. These elevations are then increased by 0.5-ft to account for

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a concrete slab foundation. These estimates are replaced with survey data and elevation certificate data where available, including over 1,100 of the 5,300 structures identified in the Phase 2 Master Plan study.

A GIS-based procedure is then applied to define structure flooding depths using a terrain model, WSEL data from the latest H&H models, GIS-based floodplain maps, and finished floor elevation data. When the elevation data is combined with a structure location map, a GIS spatial analysis can be made to estimate the depths of flooding at each structure for the 2-, 10-, 25-, and 100-year storm events. Figure 4.3-2 shows an example of the flooded structure analysis for a 25-year storm in a portion of the Williamson Creek watershed. This data is then used to calculate flood problem scores as discussed later in Section 4.5. While the previously described method appears quite simple, the amount of interrelated data is voluminous. By restricting the modeling analysis to only the primary drainage system, H&H models were utilized to reflect flooding conditions in 24 watersheds contained within or overlapping City of Austin boundaries.

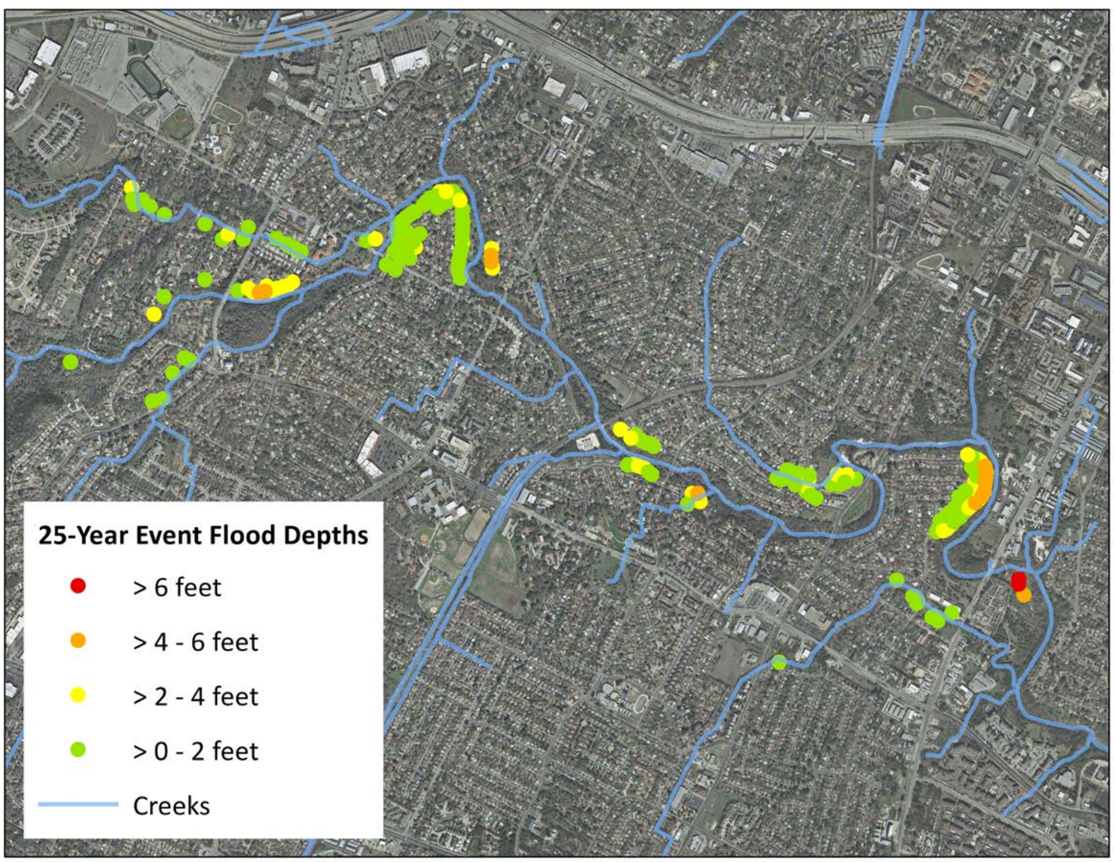

Figure 4.3-2 Flooded Structure Analysis Example in the Williamson Creek Watershed (2015)

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4.4 Resource Values

Flooding impacts several types of community resources. These include different types of residential and commercial structures and roadways as presented in Table 4.4-1. The varying numeric values reflect the level of priority for each type of resource. For example, a highway has a higher resource value (with its heavier use) than a local street (with less frequent use), and so forth.

Table 4.4-1 Resource Values

Structures		Street Crossings	
Resource Type	**Resource Value**	**Resource Type**	**Resource Value**
Public Care Facilities	100	Highway	100
Residential: Multifamily	80	Major Arterial Road	95
Mixed Use	80	Minor Arterial Road	90
Residential: Single Family	60	Collector Road	85
Non-Residential	60	Local Road	80
Parking Garage	40	Single Access	90

4.5 Problem Score

Flood problem scores are calculated separately for structures and street crossings as described below. Structural flooding caused by creek systems most frequently occurs outside of the creek but within a floodplain, and property damage is caused by the depth of water on the ground outside of the creek banks. Outside of the creek itself, the depth of water is usually more of a threat to public safety than the velocity of water. However, at roadway crossings, the velocity of water can be just as hazardous as the depth of water across the roadway. For this reason, there are two separate scoring systems. The roadway crossings have a velocity component, as shown below, while the structural scores are based solely on depth of water.

4.5.1 Flood Problem Scores for Structures

Flood problem scores for structures are calculated for all structures located in the fully developed 100-year floodplains using the following equation:

$$FT_{property} = RV * (\frac{1}{2} D_2 + \frac{1}{10} D_{10} + \frac{1}{25} D_{25} + \frac{1}{100} D_{100})$$

Where:

$FT_{property}$ = Flooding Threat to Property

RV = Resource Value

D_2 = Depth of flooding (feet) at the 2-year storm interval

D_{10} = Depth of flooding (feet) at the 10-year storm interval

D_{25} = Depth of flooding (feet) at the 25-year storm interval

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D_{100} = Depth of flooding (feet) at the 100-year storm interval

The weighting factors of 1/2 for 2-year, 1/10 for 10-year, 1/25 for 25-year, and 1/100 for 100-year are both logical (proportionate to their interval) and serve to prioritize flooding problems at more frequent storm intervals. For example, a structure flooding 1 foot at the 2-year interval will receive a problem score weighting of at least 0.50 whereas a structure flooding 1 foot at only the 100-year interval will receive a problem score weighting 0.01.

Resource values are assigned for both structures and street crossings as shown in Table 4.4-1. They serve to give more scoring weight to higher value and/or risk structures and roadways. Structure resource values are based upon land use categories. Road crossing resource values are based upon roadway classification categories.

“Raw” flood scores are thus generated for each structure using respective resource values, flooding depths at each of four flood intervals, and the weighting factors for each. These raw scores are then normalized to a maximum score of 100 to create a “final” score. This is done by dividing all raw scores in the dataset by the highest overall score and multiplying each by 100. The highest score thereby is set to 100 and all other lesser scores are proportionate to this familiar scoring number. Normalized scores are then assigned a Narrative Rating based on Structure Flood Problem Score Ratings, as shown in Table 4.5-2.

Table 4.5-2 Structure Flood Problem Score and Narrative Ratings for Individual Structures

Normalized Flood Score	Problem Score Rating	Narrative Rating
0	1	Very Low
0 - 1	2	Low
1 - 5	3	Moderate
5 - 10	4	High
10 - 100	5	Very High

In order to identify problem areas, structures are combined into “clusters” using buffer areas in GIS, with diameters assigned based on problem score ratings shown in Table 4.5-2. The higher the problem score, the larger the cluster area. This method graphically depicts the significance of the level of flooding in a manner easily displayed on a map.

All normalized scores for individual structures within a cluster are added together to generate a structure cluster score. (This methodology was revised in the Fall of 2015 to more accurately reflect flood severity in the cluster score. See Appendix A for details regarding the Fall 2015 cluster score methodology update.) Clusters are then ranked accordingly. The highest-ranking clusters are reviewed manually to combine adjacent clusters that would be assessed together for project implementation. This is only done for the higher ranking clusters to identify regional flooding problem areas for flood mitigation projects. After this analysis, clusters are re-ranked and the resulting Rank Value is used to identify top problem areas for project prioritization efforts. New narrative ratings are assigned to the clusters based on a manual assessment of the problem score data and final rank values, as depicted in Figure 4.6-3.

4.5.2 Flood Problem Scores for Street Crossings

Flood problem scores for street crossings are calculated for all streets that cross creeks within the fully developed 100-year floodplain. Problem scores for street crossings are very similar to those for structures, except that they include an additional velocity component; in the following equation:

$$FT_{crossing} = RV * (\frac{1}{2} D_2 * V_2 + \frac{1}{10} D_{10} * V_{10} + \frac{1}{25} D_{25} * V_{25} + \frac{1}{100} D_{100} * V_{100})$$

Where:
$FT_{crossing}$ = Flooding Threat to Roadway Crossing
RV = Resource Value
D_2 = Depth of flooding (feet) at the 2-year storm interval
D_{10} = Depth of flooding (feet) at the 10-year storm interval
D_{25} = Depth of flooding (feet) at the 25-year storm interval
D_{100} = Depth of flooding (feet) at the 100-year storm interval
V_2 = Velocity of flooding (ft/sec) at the 2-year storm interval
V_{10} = Velocity of flooding (ft/sec) at the 10-year storm interval
V_{25} = Velocity of flooding (ft/sec) at the 25-year storm interval
V_{100} = Velocity of flooding (ft/sec) at the 100-year storm interval

The velocity component underscores the impact of moving water on public safety for flooded roadway crossings. The remainder of the process to derive final scores is the same as that used for structure flooding, with the added velocity component. “Raw” scores are generated for each crossing using respective resource values, flooding depths and velocities at each of four flood intervals, and the weighting factors for each. The raw scores are normalized to a maximum score of 100 to create a “final” score. Normalized scores are then assigned a Problem Score Rating and Narrative Rating as shown in Table 4.5-2.

4.6 Results

This section presents the results of creek flooding analysis for the 30 core watersheds for which problem scoring data is available.[5] Because the department initiates Capital Improvement Program (CIP) project solutions in the City’s full purpose jurisdiction, the following discussion focuses primarily on the problem data for the full purpose jurisdiction. Problem score data are also calculated for

[5] Data for additional watersheds is scheduled for completion in the future, as presented above in Table 4.3-2.

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the limited purpose and extraterritorial jurisdiction (ETJ) areas, in order for the department to prepare for potential annexations and project partnering opportunities with other government entities. These problem data are included for reference in the watershed summary maps and tables. The results use data produced in October 2015. Scoring information changes over time with jurisdictional annexations, implemented capital solutions, and improved modeling and mapping data. The results data do not reflect the City of Austin's most recent structural buyouts as this information is updated annually.

4.6.1 Structural Flooding Results

Table 4.6-1 summarizes creek flooding problem data for primary structures for the full purpose and extraterritorial/limited purpose jurisdictions. The 100-year storm is the baseline of flood impact assessment. In both the full and extraterritorial/limited purpose jurisdictions, all of the 30 evaluated watersheds are estimated to have some level of structure flooding in a 100-year storm event, with 5,455 primary structures within the 100-year fully developed floodplain. Of these structures, 2,672 are estimated to experience inundation in a 100-year storm. (Those structures in the floodplain but not estimated to be inundated are still tracked, because, while inundation might be less of a concern, safe access to non-flooded areas during a storm event may be a concern.) In the full purpose jurisdiction only, 4,788 primary structures within the 100-year fully developed floodplain and 2,207 estimated to experience inundation in a 100-year storm.

Figure 4.6-1 Onion Creek Flooding, October 2013.

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The majority of all structures estimated to be inundated by the 100-year storm are located in some of Austin's larger waterways, such as Onion, Williamson, Shoal, and Little Walnut Creeks. These watersheds account for 67% of all the inundated structures within the full purpose jurisdiction, with Onion Creek alone containing 24% of the total with 539 structures. However, many watersheds with the most severe scores (High to Very High), such as Boggy and Waller, are not the watersheds with the largest drainage areas. Applying the same methodology to flood scoring across all watersheds allows the City to determine the relative risk of flooding regardless of watershed or floodplain area. Figure 4.6-1 shows both roadway and residential flooding in the Onion Creek watershed.

Structures suffering inundation in the 2-year design storm receive the most points in the scoring system, making them a high priority for solution development (see Section 10) due to the high probability of repeated threats to life, safety, and property compared to structures in areas less frequently flooded (i.e., 10-, 25-, and 100-year floodplains). In both the full and extraterritorial/limited purpose jurisdictions, 14 evaluated watersheds are estimated to have structure flooding in a 2-year storm event, with 55 total structures experiencing inundation. Thirty-seven of those structures are within the full purpose jurisdiction. Structures are generally found in the 2-year floodplain in older neighborhoods in the urban core (e.g., Shoal, West Bouldin, and Waller) or in more recently annexed areas in outlying watersheds (e.g., Carson and Dry East) where structures were placed in floodplains and upstream areas were developed without flood detention in an era prior to watershed regulations and/or a more modern understanding of urban buildout and floodplain determination. Carson Creek watershed has the most structures inundated in a 2-year storm event with 18.

Figure 4.6-2 displays the data from Table 4.6-1 in a bar chart. The blue portions of the bars represent the number of structures inundated by the 2-, 10-, 25-, and 100-year storms, while the grey portions represent the number of structures that are in the 100-year floodplain, but are not expected to be inundated. While the Onion Creek watershed has largest number of inundated structures, Williamson Creek has the most structures in the 100-year floodplain.

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*Table 4.6-1 Summary by Watershed: Estimates of Structures in 100-year Floodplain and at Risk of Inundation, Full Purpose and Extraterritorial/Limited Purpose Jurisdiction (October 2015)**

Watershed	Phase	Full Purpose					Extraterritorial/Limited Purpose					Total	
		Structures in 100-yr Floodplain	Inundated Structures Count by Flood Frequency				Structures in 100-yr Floodplain	Inundated Structures Count by Flood Frequency				Structures in 100-yr Floodplain	% Total in 100-yr Floodplain
			2-yr	10-yr	25-yr	100-yr		2-yr	10-yr	25-yr	100-yr		
Barton (Gaines)	1	42	1	3	8	19	0	0	0	0	0	42	1%
Blunn	1	12	0	0	0	1	0	0	0	0	0	12	0%
Boggy	1	139	1	17	28	51	0	0	0	0	0	139	3%
Bull	1	55	0	0	10	21	11	0	1	3	6	66	1%
Buttermilk	1	5	0	0	0	0	0	0	0	0	0	5	0%
Carson	2	123	18	31	49	73	7	0	0	0	0	130	2%
Cottonmouth	2	0	0	0	0	0	11	2	3	4	9	11	0%
Country Club East	1	12	0	0	0	1	0	0	0	0	0	12	0%
Country Club West	1	45	0	4	5	9	0	0	0	0	0	45	1%
Decker	2	0	0	0	0	0	11	2	8	10	11	11	0%
Dry East	2	1	0	0	0	0	58	9	34	50	55	59	1%
Dry North	2	18	0	0	1	1	0	0	0	0	0	18	0%
East Bouldin	1	67	0	0	6	16	0	0	0	0	0	67	1%
Elm	2	0	0	0	0	0	42	4	26	12	21	42	1%
Fort	1	304	1	12	42	134	0	0	0	0	0	304	6%
Gilleland	2	0	0	0	0	0	8	1	6	8	8	8	0%
Harris Branch	2	1	0	0	0	1	56	0	10	25	34	57	1%
Johnson	1	56	0	2	5	8	0	0	0	0	0	56	1%
Little Walnut	1	422	0	21	67	197	0	0	0	0	0	422	8%
Marble	2	0	0	0	0	0	1	0	0	0	0	1	0%
Onion	2	586**	0	30	123	539	279	0	73	157	236	865**	16%
Rinard †	2	1	0	0	0	0	0	0	0	0	0	1	0%
Shoal	1	665	6	67	127	274	0	0	0	0	0	665	12%
Slaughter	2	52	0	0	0	16	53	0	0	1	19	105	2%
South Boggy	2	52	0	2	13	18	73	0	0	19	37	125	2%
Tannehill Branch	1	369	0	1	10	109	0	0	0	0	0	369	7%
Waller	1	368	1	21	44	122	0	0	0	0	0	368	7%
Walnut	1	248	5	23	45	82	53	0	5	16	28	301	6%
West Bouldin	1	114	2	11	17	42	0	0	0	0	0	114	2%
West Bull	2	1	0	0	0	0	2	0	0	0	0	3	0%
Williamson	1	1,030**	2	58	193	473	2	0	1	1	1	1,032**	19%
Totals:		**4,788****	**37**	**303**	**793**	**2,207**	**667**	**18**	**167**	**306**	**465**	**5,455****	**100%**
Maximum Value:		1,030**	18	67	193	539	279	9	73	157	236	1,032**	19%

** This data will change as new models and better information become available, non-habitable structures are identified, and solutions are implemented*

*** An additional 215 structures from Onion and 28 from Williamson have been removed from the floodplain as of July 2016 via property buyouts; the resulting total number of structures in the floodplain in the full-purpose jurisdiction has thus fallen from 4,788 to 4,545.*

† Structure in Rinard watershed located in Onion Creek floodplain. Comprehensive problem score data for the Rinard watershed will be included in a future update, once detailed models and problem score data become available for the watershed (see Table 4.3-2).

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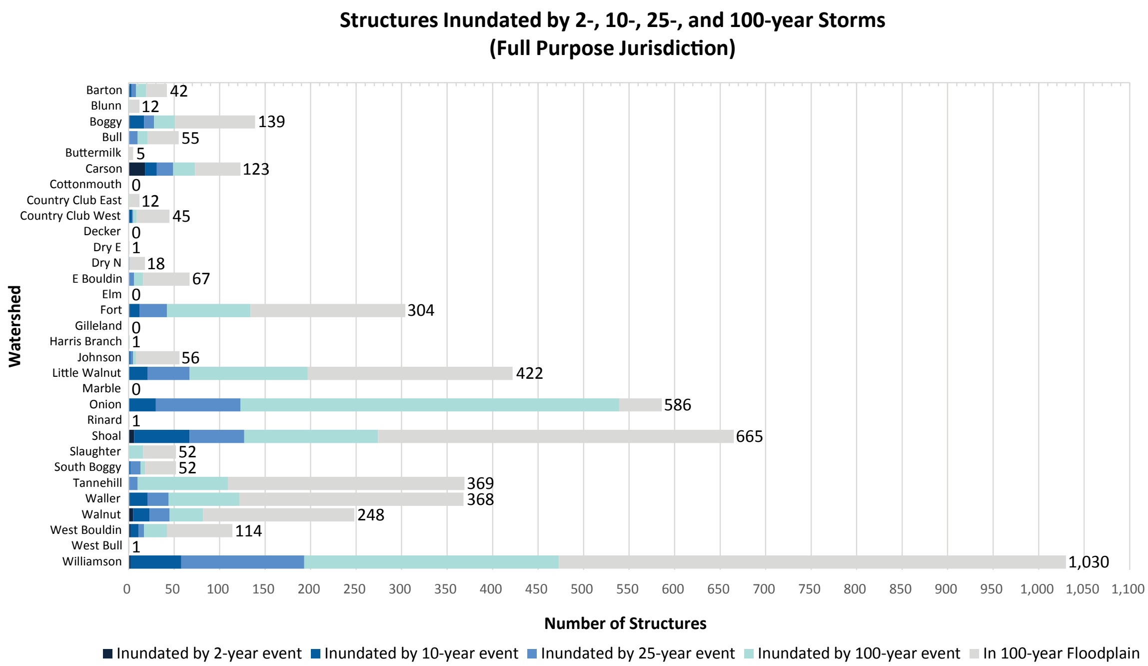

Figure 4.6-2 Structures Inundated by 2-, 10-, 25-, and 100-year Storms (Oct. 2015; Full Purpose Jurisdiction)

Table 4.6-2 presents problem score data by watershed for structure clusters per the scoring methodology. Unsurprisingly, those watersheds with a large number of inundated structures in a 100-year storm event also tend to have a large percentage of high scoring structure clusters. The Onion Creek watershed continues to account for the largest percentage of the scores, comprising 33% of the scores (111 of 335) in the full purpose jurisdiction and fully 60% of the scores (75 of 124) in the limited purpose jurisdiction. Shoal, Williamson, Carson, Walnut, and Waller together comprise over 56% of the rest of the total score (186 of 335) within the full purpose jurisdiction, with Williamson containing the most structure clusters with 49. Figure 4.6-3 presents this information geospatially, with red structure clusters representing those with Very High problem scores. These Very High problem score structure clusters tend to be found near one another, as can be seen in Onion, Williamson, Shoal, and Little Walnut watersheds.

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*Table 4.6-2 Problem Score Summary by Watershed: Creek Flood Structure Clusters (October 2015)**

Watershed	Phase	Full Purpose Structure Clusters			ETJ/Limited Purpose Structure Clusters		
		Count	Total Score	Pct. Total Score	Count	Total Score	Pct. Total Score
Barton (Gaines)	1	1	1	0.3%	0	0	0.0%
Blunn	1	1	0	0.0%	0	0	0.0%
Boggy	1	10	8	2.5%	0	0	0.0%
Bull	1	11	2	0.5%	6	1	1.2%
Buttermilk	1	0	0	0.0%	0	0	0.0%
Carson	2	14	38	11.5%	0	0	0.0%
Cottonmouth	2	0	0	0.0%	0	0	0.0%
Country Club East	1	1	0	0.0%	0	0	0.0%
Country Club West	1	7	1	0.2%	0	0	0.0%
Decker	2	0	0	0.0%	9	3	2.7%
Dry East	2	0	0	0.0%	25	20	16.0%
Dry North	2	1	0	0.1%	0	0	0.0%
East Bouldin	1	15	0	0.1%	0	0	0.0%
Elm	2	0	0	0.0%	22	4	3.4%
Fort Branch	1	36	6	1.9%	0	0	0.0%
Gilleland	2	0	0	0.0%	6	4	2.8%
Harris Branch	2	1	0	0.0%	5	3	2.2%
Johnson	1	5	1	0.2%	0	0	0.0%
Little Walnut	1	36	9	2.7%	0	0	0.0%
Marble	2	3	1	0.2%	0	0	0.0%
Onion	2	9	111	33.0%	45	75	60.6%
Rinard	2	0	0	0.0%	0	0	0.0%
Shoal	1	45	60	17.9%	0	0	0.0%
Slaughter	2	3	0	0.1%	15	0	0.3%
South Boggy	2	8	2	0.6%	18	5	3.8%
Tannehill Branch	1	6	1	0.4%	0	0	0.0%
West Bouldin	1	20	6	1.7%	0	0	0.0%
West Bull	2	0	0	0.0%	0	0	0.0%
Waller	1	28	16	4.7%	0	0	0.0%
Walnut	1	31	19	5.5%	13	9	6.9%
Williamson	1	49	53	16.0%	1	0	0.2%
Totals:		**341**	**335**	**100.0%**	**165**	**124**	**100.0%**
Maximum Value:		49	111	33.0%	45	75	60.6%

** This data will change as new models and better information become available, non-habitable structures are identified, and solutions are implemented*

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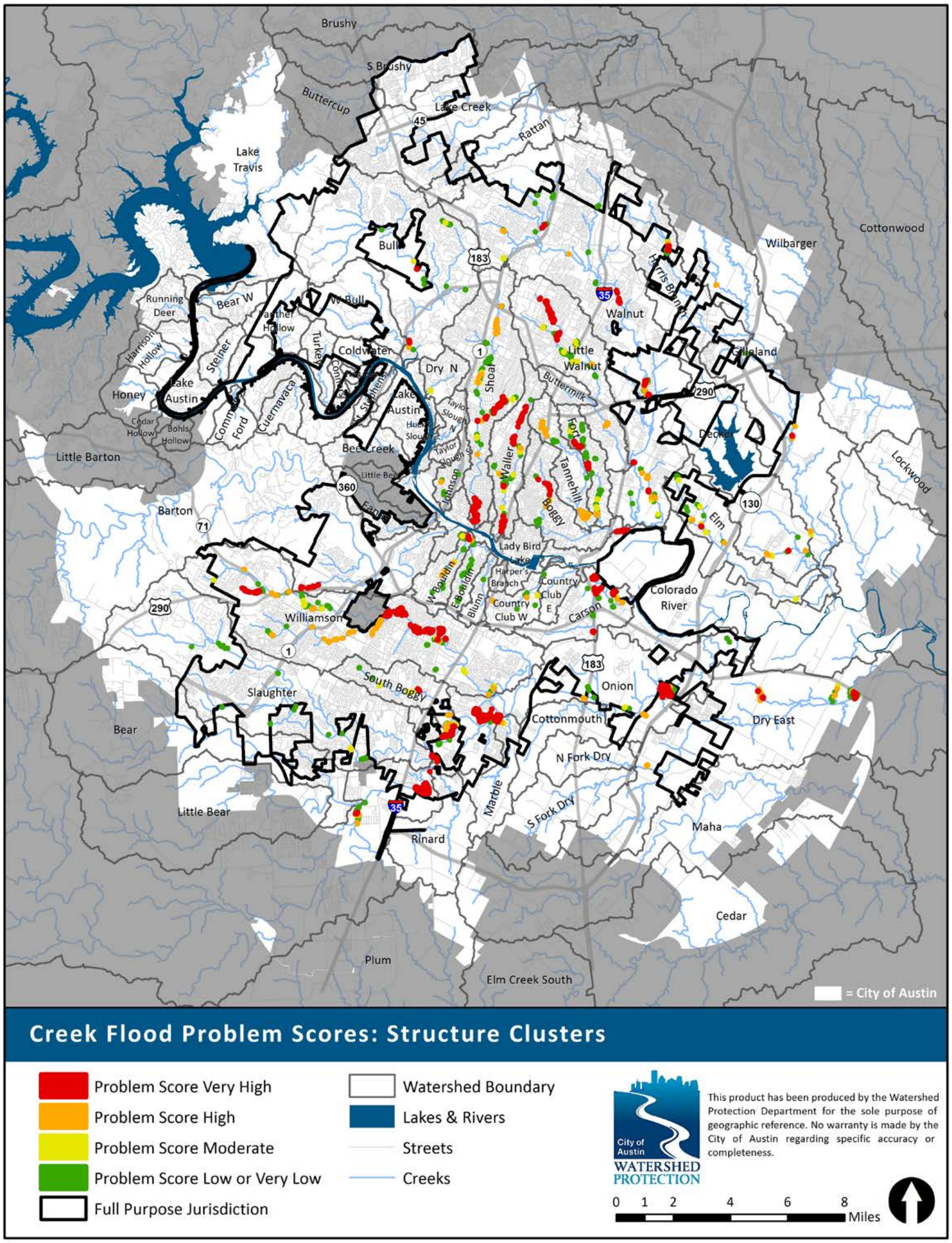

Figure 4.6-3 Creek Flood Problem Scores: Structure Clusters by Watershed (October 2015)

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Figure 4.6-4 graphically displays the creek flood problem score distribution, showing that the scores become gradually distributed after an initial score spike. Figure 4.6-5 shows just the Top 20 problem scores in more detail, revealing that the top scoring structure cluster (Onion Creek Buyouts) scores much higher than the cluster with the next highest score (Lower Shoal Creek), which scores less than 50. Thereafter, the scores become much more gradually distributed.

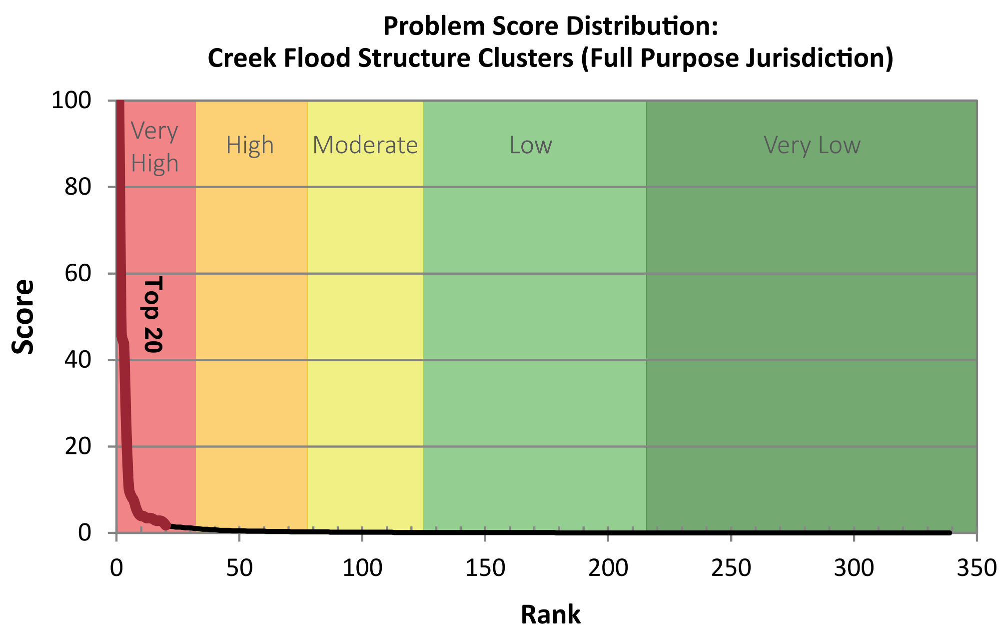

Figure 4.6-4 Problem Score Distribution: Creek Flood Structure Clusters (Oct. 2015; Full Purpose Jurisdiction)

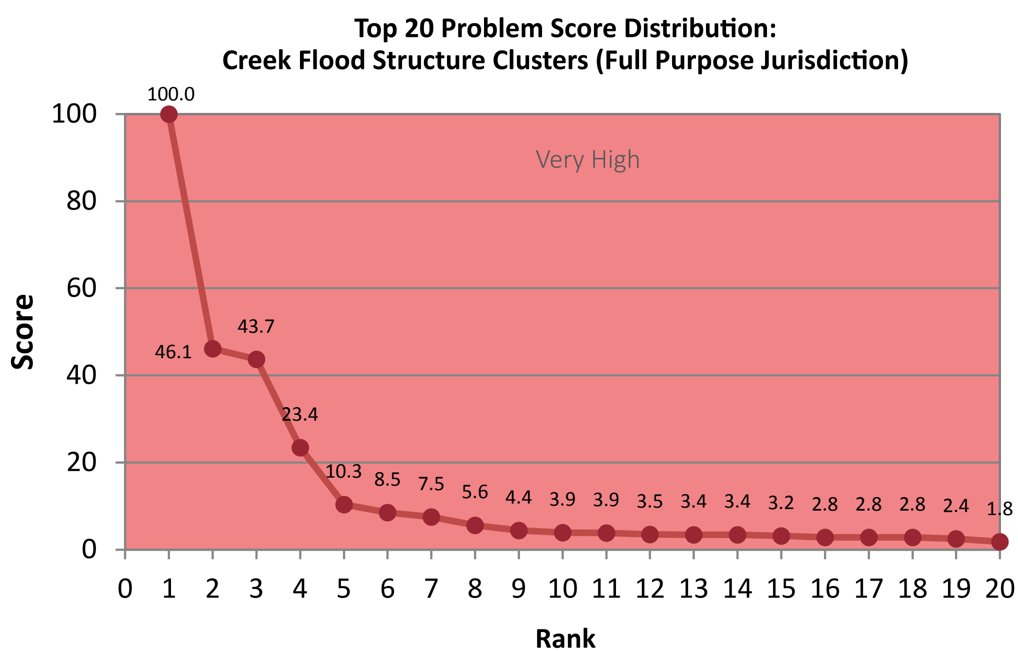

Figure 4.6-5 Top 20 Problem Score Distribution: Creek Flood Structure Clusters (Oct.2015; Full Purpose Jurisdiction)

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Lastly, Table 4.6-3 presents each of the Top 20 problem score clusters by name, watershed, and score. Section 10 presents the methodology by which problem areas are prioritized for solution implementation, which considers not only the problem severity but also other factors, such as cost and technical feasibility.

*Table 4.6-3 Top 20 Ranked Problem Scores: Creek Flood Structure Clusters (Oct. 2015; Full Purpose Jurisdiction)**

Problem Score Rank	Problem Area Name (Structure Cluster Name)	Watershed	Score
1	Lower Onion Creek Buyouts	Onion	100.0
2	Lower Shoal Creek	Shoal	46.1
3	Cherry Creek to S Congress Ave	Williamson	43.7
4	Metropolis Dr at US 183	Carson	23.4
5	Pinehurst Dr Subdivision & Wild Dunes	Onion	10.3
6	Waller Creek Tunnel	Waller	8.5
7	Bastrop Hwy and Patton Ave	Carson	7.5
8	Shoal Creek at Hancock Tributary	Shoal	5.6
9	Carson Creek at Dalton Ln	Carson	4.4
10	February Dr and River Oaks Trail	Walnut	3.9
11	Shelton Rd at Delwau Ln	Boggy	3.9
12	Metric Blvd to Rutland Dr	Little Walnut	3.5
13	Barton Springs Rd at West Bouldin	West Bouldin	3.4
14	Walnut at FM 969	Walnut	3.4
15	E 38 1/2 St to E MLK Blvd	Boggy	3.2
16	Upper Little Walnut at Quail Cove	Little Walnut	2.8
17	Berkman Dr to Waterbrook Dr	Fort Branch	2.8
18	Walnut at US 183	Walnut	2.8
19	Walnut at Waters Park Rd	Walnut	2.4
20	Shoal Creek Blvd and 49th St	Shoal	1.8

** This data will change as new models and better information become available, non-habitable structures are identified, and solutions are implemented*

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4.6.2 Roadway Crossing Flooding Results

There are over 700 roadways that cross creek systems (as derived from City of Austin hydraulic models) within the full and extraterritorial/limited purpose jurisdictions of the 30 core watersheds. Of the roadways in the full purpose jurisdiction, approximately 393 are estimated to experience some level of inundation over the roadway in a 100-year event and 94 would experience flooding in a 2-year event (See Table 4.6-4). Whereas most of the inundated structures tend to be concentrated in a few watersheds, inundated roadways are more evenly distributed across all watersheds. While the top three watersheds for inundated structures in the full purpose jurisdiction comprise over 66% of the total score, the top three watersheds for roadways inundated in the 100-year storm comprise only 36% of the total score (see Table 4.6-2 and 4.6-5).

This phenomenon is graphically depicted in Figure 4.6-6. While larger watersheds such as Walnut, Williamson, and Shoal are among the top five watersheds for roadways at risk of inundation in an 100-year event (full purpose), other large watersheds have relatively few inundated roadways. Onion Creek, which is the leading watershed for inundated structures, has only three roadways at risk of inundation in an 100-year event. As expected, more urbanized watersheds have a higher density of road crossings and more inundation problems than do outlying, less urbanized watersheds. And older bridges and culverts tend to have more inundation concerns, as many were built without a modern understanding of expected urban buildout and flooding levels.

Table 4.6-5 presents the count of road crossings by flooding severity, from Low to Very High. In the full purpose jurisdiction, Williamson Creek has the highest number of “very high” problem score crossings with nine, followed by Waller and Walnut with eight and seven, respectively. Williamson Creek also has the highest percent of the overall score with over 13% of the total score. Figure 4.6-7 graphically depicts the same data, with red points representing road crossings with Very High problem scores.

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*Table 4.6-4 Summary by Watershed: Estimates of Roadways in 100-year Floodplain and at Risk of Inundation, Full Purpose and Extraterritorial/Limited Purpose Jurisdiction (October 2015)**

Watershed	Phase	Full Purpose					Extraterritorial/Limited Purpose					Total	
		Roadways in 100-yr Floodplain	Inundated Roadways Count by Flood Frequency				Roadways in 100-yr Floodplain	Inundated Structures Count by Flood Frequency				Roadways in 100-yr Floodplain	% Total in 100-yr Floodplain
			2-yr	10-yr	25-yr	100-yr		2-yr	10-yr	25-yr	100-yr		
Barton (Gaines)	1	7	5	5	5	7	0	0	0	0	0	7	1.0%
Blunn	1	9	0	1	6	7	0	0	0	0	0	9	1.3%
Boggy	1	25	1	8	11	13	0	0	0	0	0	25	3.5%
Bull	1	32	4	9	13	17	10	8	8	8	8	42	5.9%
Buttermilk	1	4	0	0	1	3	0	0	0	0	0	4	0.6%
Carson	2	16	5	12	12	15	0	0	0	0	0	16	2.2%
Cottonmouth	2	0	0	0	0	0	7	2	4	4	6	7	1.0%
Country Club East	1	10	2	2	3	6	0	0	0	0	0	10	1.4%
Country Club West	1	22	5	7	11	12	0	0	0	0	0	22	3.1%
Decker	2	7	1	1	2	2	12	6	7	7	7	19	2.7%
Dry East	2	0	0	0	0	0	21	6	14	16	16	21	2.9%
Dry North	2	15	4	7	9	13	0	0	0	0	0	15	2.1%
East Bouldin	1	16	2	11	13	14	0	0	0	0	0	16	2.2%
Elm	2	0	0	0	0	0	18	6	8	12	12	18	2.5%
Fort	1	23	5	18	22	22	0	0	0	0	0	23	3.2%
Gilleland	2	3	0	0	1	1	17	1	5	6	11	20	2.8%
Harris Branch	2	8	2	2	2	2	12	3	4	5	6	20	2.8%
Johnson	1	21	3	7	8	12	0	0	0	0	0	21	2.9%
Little Walnut	1	31	2	13	14	20	0	0	0	0	0	31	4.4%
Marble	2	2	1	1	1	1	2	0	2	2	2	4	0.6%
Onion	2	7	1	3	3	3	8	1	3	4	5	15	2.1%
Rinard	2	0	0	0	0	0	0	0	0	0	0	0	0.0%
Shoal	1	54	11	35	41	46	0	0	0	0	0	54	7.6%
Slaughter	2	22	3	3	3	4	12	8	9	11	12	34	4.8%
South Boggy	2	13	1	1	8	11	1	0	0	0	0	14	2.0%
Tannehill Branch	1	25	2	11	13	19	0	0	0	0	0	25	3.5%
Waller	1	49	14	31	38	45	0	0	0	0	0	49	6.9%
Walnut	1	58	8	13	18	28	10	3	4	6	7	68	9.6%
West Bouldin	1	13	1	6	9	12	0	0	0	0	0	13	1.8%
West Bull	2	13	1	1	4	9	1	0	0	0	1	14	2.0%
Williamson	1	75	10	27	39	49	1	1	1	1	1	76	10.7%
Totals:		**580**	**94**	**235**	**310**	**393**	**132**	**45**	**69**	**82**	**94**	**712**	**100.0%**
Maximum Value:		75	14	35	41	49	21	8	14	16	16	76	10.7%

** This data will change as solutions are implemented and new models and better information become available.*

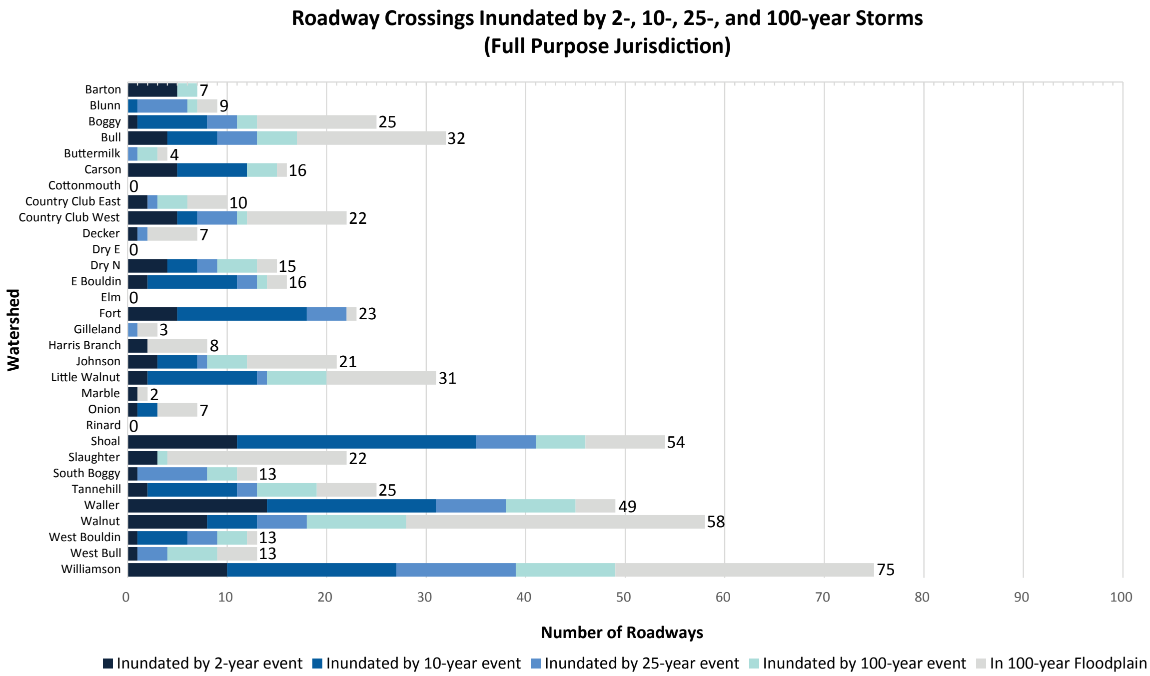

Figure 4.6-6 Roadways Inundated by 2-, 10-, 25-, and 100-year Storms (Oct. 2015; Full Purpose Jurisdiction)

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*Table 4.6-5 Problem Severity by Watershed: Creek Flood Street Crossings (Oct. 2015; Full Purpose Jurisdiction)**

Watershed	Phase	Count by Severity					Total Score	Pct. Total Score
		Low	Med.	High	Very High	Total Count		
Barton (Gaines)	1	2	2	2	1	7	29	1.5%
Blunn	1	4	3	0	0	7	8	0.5%
Boggy	1	7	5	0	1	13	47	2.5%
Bull	1	7	5	0	5	17	201	10.8%
Buttermilk	1	3	0	0	0	3	1	0.0%
Carson	2	7	2	2	4	15	70	3.8%
Cottonmouth	2	0	0	0	0	0	0	0.0%
Country Club East	1	5	0	0	1	6	13	0.7%
Country Club West	1	6	4	1	1	12	27	1.4%
Decker	2	1	1	0	0	2	2	0.1%
Dry East	2	0	0	0	0	0	0	0.0%
Dry North	2	6	2	1	3	12	106	5.7%
East Bouldin	1	3	7	3	1	14	59	3.2%
Elm	2	0	0	0	0	0	0	0.0%
Fort Branch	1	2	12	5	3	22	86	4.6%
Gilleland	2	1	0	0	0	1	0	0.0%
Harris Branch	2	0	0	1	1	2	36	1.9%
Johnson	1	6	3	0	3	12	40	2.1%
Little Walnut	1	8	8	3	1	20	56	3.0%
Marble	2	0	0	0	1	1	14	0.7%
Onion	2	0	0	0	3	3	44	2.4%
Shoal	1	10	22	8	6	46	231	12.4%
Slaughter	2	1	0	0	3	4	82	4.4%
South Boggy	2	5	5	0	1	11	20	1.1%
Tannehill Branch	1	9	7	3	0	19	35	1.9%
West Bouldin	1	7	2	3	0	12	25	1.3%
West Bull	1	5	3	1	0	9	11	0.6%
Waller	1	12	16	9	8	45	187	10.0%
Walnut	1	14	2	5	7	28	188	10.1%
Williamson	1	21	14	5	9	49	249	13.3%
Totals:		**152**	**125**	**52**	**63**	**392**	**1,866**	**100.0%**
Maximum Value:		21	22	9	9	49	249	13.3%

** This data will change as solutions are implemented and new models and better information become available.*

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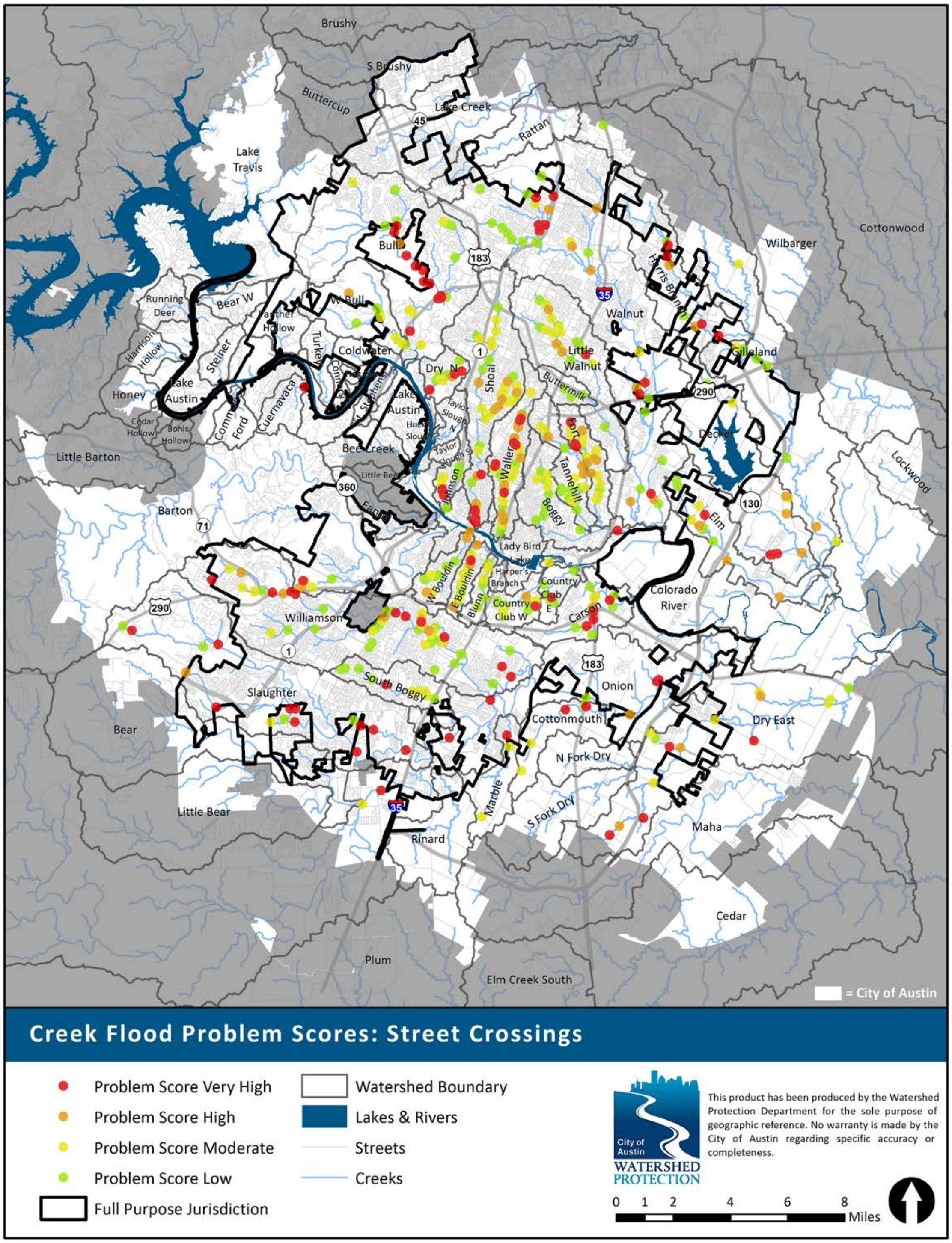

Figure 4.6-7 Creek Flood Problem Scores: Street Crossings by Watershed (October 2015)

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Figure 4.6-8 graphically displays the street crossings problem score distribution. Unlike the flooded structures distribution, problem scores do not level out until after the top 200 street crossings, meaning there are many more street crossings than there are flood clusters with Very High scores. Since the scoring system proportionately weights crossings inundated in the 2- and 10-year storm event higher than those in less frequent events (25- and 100-year events, respectively) and more highly ranks locations with fast flow velocities, this large number of Very High scores indicates that a significant number of crossings are modeled to be inundated at these levels and/or would experience dangerous flow velocities.

Figure 4.6-9 zooms into the Top 20 problem scores for the full purpose jurisdiction, with Table 4.6-6 giving the location and score for each street crossing. Whereas the structure cluster scores drastically diminish after the first two clusters, the Top 20 street crossing scores are much more gradually distributed.

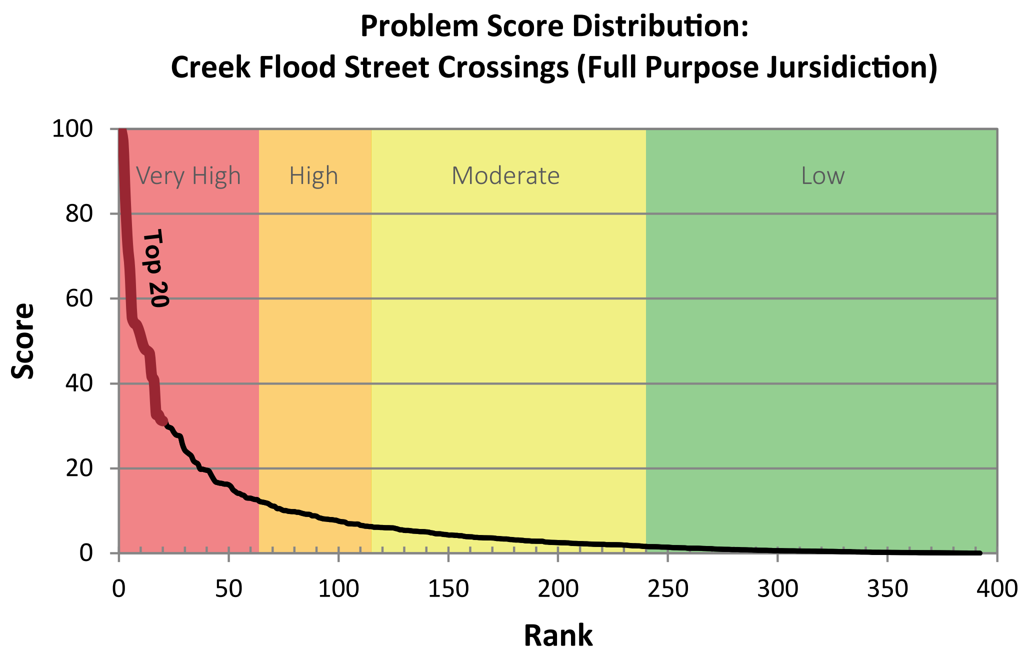

Figure 4.6-8 Problem Score Distribution: Creek Flood Street Crossings (Oct. 2015; Full Purpose Jurisdiction)

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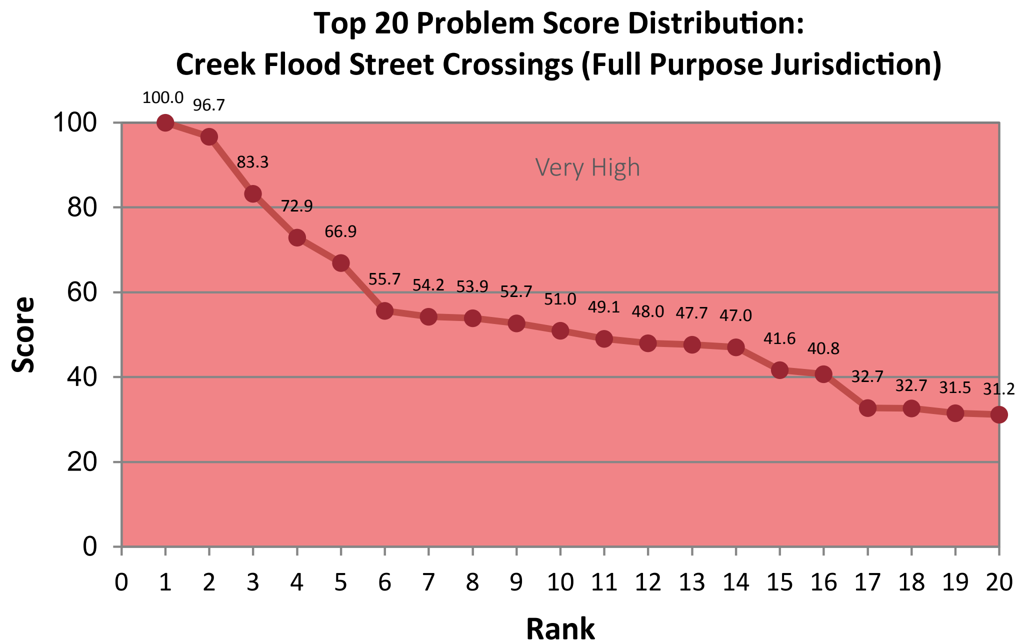

Figure 4.6-9 Top 20 Problem Score Distribution: Creek Flood Street Crossings (Oct.2015; Full Purpose Jurisdiction)

*Table 4.6-6 Top 20 Ranked Problem Scores: Creek Flood Street Crossings (Oct. 2015; Full Purpose Jurisdiction)**

Problem Score Rank	Problem Area Name (Street Name)	Watershed	Score
1	Old Spicewood Springs Rd	Bull	100.0
2	Mount Bonnell Rd	Dry Creek North	96.7
3	W 9th St	Shoal	83.3
4	Old San Antonio Rd	Slaughter	72.9
5	Jimmy Clay Dr	Williamson	66.9
6	Old Spicewood Springs Rd	Bull	55.7
7	Delwau Ln	Boggy	54.2
8	Waters Park Rd	Walnut	53.9
9	Wasson Rd	Williamson	52.7
10	Lakewood Dr	Bull	51.0
11	Old Spicewood Springs Rd	Bull	49.1
12	W 10th St	Shoal	48.0
13	Old Bee Caves Rd	Williamson	47.7
14	Cameron Rd	Harris Branch	47.0
15	McNeil Dr	Walnut	41.6
16	W Monroe St	East Bouldin	40.8
17	Nuckols Crossing Rd	Williamson	32.7
18	N Capital of Texas Highway	Bull	32.7
19	Shoal Creek Blvd	Shoal	31.5
20	Fiskville Cemetary Rd	Little Walnut	31.2

** This data will change as solutions are implemented and new models and better information become available.*

5 Local Flooding Assessment

5.1 Background

The secondary, or “local” drainage system is composed of pipes, curb inlets, manholes, minor channels, roadside ditches, and culverts. WPD operates and maintains approximately 1,100 miles of storm drain pipes, ranging in diameter from 6 inches to 24 feet. In addition to minor channels and borrow ditches, the system includes over 27,000 curb inlets. This system is intended to convey stormwater runoff to the primary drainage system, the creeks. Many of Austin’s local drainage systems are very old—over 19% of the system was built prior to the regulatory adoption of modern engineering criteria in 1977. These older systems may be undersized and/or experience failure of components due to aging materials. Both can contribute to local flooding.

“Local flooding” is the term given to areas where flooding occurs due to problems with this secondary drainage system. Problems with the primary system are termed “creek flooding” (see Section 4), and are commonly associated with the 100-year floodplain area of a given watershed. There may be a possibility of local flooding occurring within the 100-year floodplain even though the storm impacting the local system is smaller than a 100-year event. A study of records from the 3-1-1 database revealed that more customers with property located outside the regulated 100-year floodplain file drainage complaints than do customers within the 100-year floodplain.

5.2 Overview of Assessment Methodology

Section 5 describes the methods used to investigate problems associated with the secondary drainage system. The methodology takes citywide local flooding information derived from citizen complaint data, ranks problems by severity, and proposes a list of Top 20 problem areas. Solutions to these problems are discussed later in Section 10. Methods used to investigate “creek flooding” associated with the primary drainage system are reviewed in Section 4.

Figure 5.2-1 graphically presents the methodology for local flooding.

1. **Collect Data on Building, Yard, and Street Flooding.** Complaint Points, representing Building, Yard, and Street Flooding Complaints, are geocoded into GIS from the City of Austin 3-1-1 Complaint Database.

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2. **Generate Problem Scores.** Complaint Clusters are created in GIS, consisting of 5 or more complaint points within 150 feet of each other. Problem Areas are delineated around complaint clusters, scored by counting complaints within the boundary, and ranked by total count of Building Complaints, then Yard Complaints, then Street Complaints. In cases where there is more than one complaint at the same address, only the most severe complaint is counted. The 20 highest scoring (ranking) problem areas are identified.

3. **Prioritize Problems for CIP Solution Integration.** High ranking problem areas are further evaluated for site-specific feasibility considerations. Section 10 discusses how projects are developed and prioritized from priority problem areas.

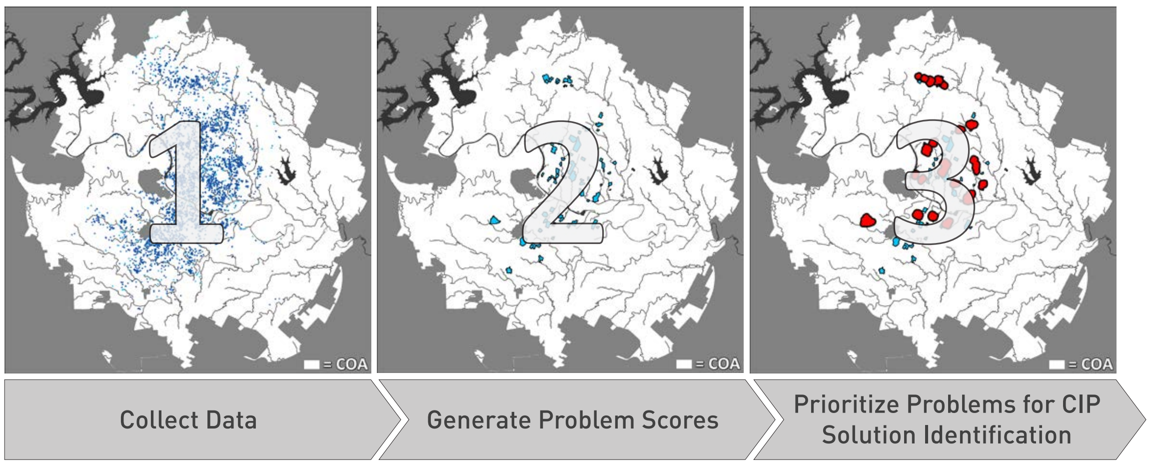

Figure 5.2-1 Local Flood Prioritization Methodology (2015). Steps 1 & 2 are described here in Section 5, while Step 3 is described in Section 10.

5.3 Sources of Local Flooding Problems

The integrity and performance level of storm drain systems is highly dependent on three factors: material selection, design, and quality of construction. Austin's older storm drain systems are impacted by a combination of these factors, leading to local flooding problems. Understanding the origin of potential problems is the first step in assessing problem severity. Quality of construction is self-evident in importance: proper design, plan review, and construction inspection are all required to ensure high quality construction. The other two factors, material selection and design, are discussed below in detail as these have led to significant local flooding problems.

5.3.1 Material Selection

Historically, the predominant storm drain pipe materials used in Austin have been vitrified clay, non-reinforced concrete, and reinforced concrete. The first material used for enclosed storm drains was vitrified clay pipe. This material, while resistant to corrosion, is fragile, and susceptible to breaking when disturbed by construction or soil movement. In Austin, vitrified clay pipe was probably installed

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around the 1890s to early 1900s and is still present in parts of downtown, the Enfield area, and the Hyde Park neighborhood. Non-reinforced concrete pipe is a cylindrical concrete pipe without steel reinforcement. This material was used predominantly in the 1930s to early 1960s. Non-reinforced concrete pipe is commonly found in the older parts of the City developed during this time period. Experience has shown that in Austin, non-reinforced concrete pipe has a service life of about 40 years. Unfortunately, without the steel reinforcement, it has a relatively short service life and is subject to collapse and the need for frequent replacement. Although developed much earlier, reinforced concrete pipe (RCP) was not commonly used as a cost-effective solution until the early 1960s. It has a design life of more than 50 years; under ideal conditions, the life of the pipe can exceed 75 years.

5.3.2 Design Criteria

Just as materials selection has evolved over time, City drainage design criteria have also changed significantly over the years. The earliest criteria for designing storm drains can be found in the 1954 City Code. It set the minimum requirement of computing total runoff to be not less than 2.6 cubic feet per second (cfs) per acre. The Rational Method was developed in the mid-1800s and is commonly used to size storm drains, but this method was not formally introduced as part of City criteria until the first edition of the City's Drainage Criteria Manual (DCM) in 1977. It is not clear what methods were accepted for determining excess runoff prior to 1977. As a comparison, the 1954 minimum criteria of 2.6 cfs per acre would more likely be about 5 to 7 cfs per acre, on average, for most fully developed residential areas under the City's current criteria. This means that the older storm drain capacities may be undersized by a factor of 2 to 3 times under today's standards.

Curb inlets are used to get water off streets and into storm drainage systems. Old, undersized curb inlets are found throughout the City. Some of the smallest are only 18 inches in length. About 3,500 inlets in the City are 5 feet or smaller in length, comprising approximately 12% of all the inlets in the City. While some five foot inlets might be adequate for small drainage areas, many are undersized. Lastly, in various parts of town, there are no storm drains at all. Excess runoff was apparently designed to flow along city streets and in minor, open channels, sometimes between houses or businesses. WPD classifies storm drains as "old" or "outdated" if they were designed and/or installed under drainage criteria in effect before January 1977 (the date of the first DCM). As of 2016, at least 214 miles of conduit were built before 1977, approximately 19% of the total storm drain system. These older systems, as mentioned above, are more at risk of structural failure due to deterioration with age, insufficient design criteria, and/or poor materials, leading to local flooding issues. Figure 5.3-1 shows the location of storm drainage systems constructed before 1977. As expected, most are in the central core of the City, where much of the development predates modern drainage criteria.

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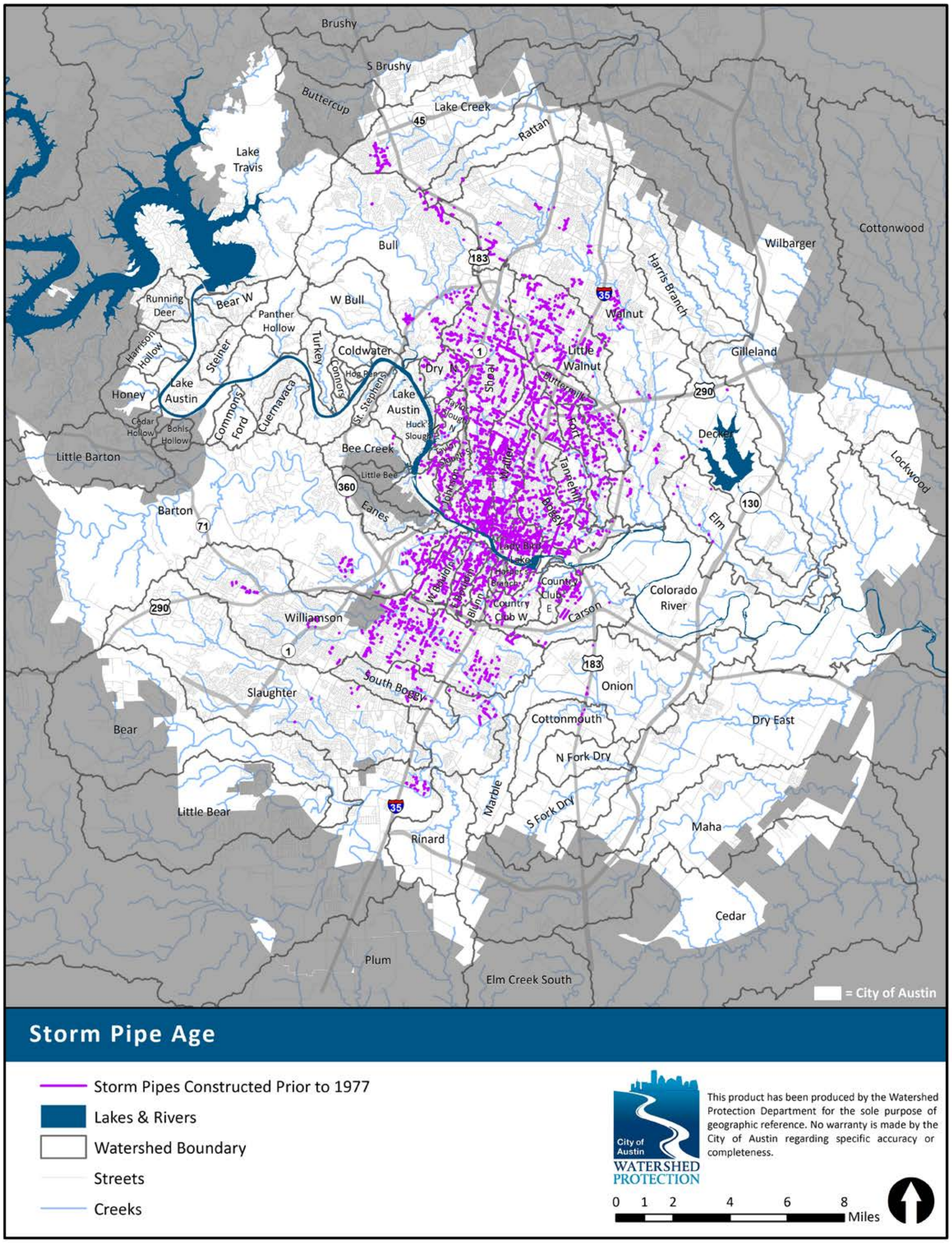

Figure 5.3-1 Storm Pipes Built Prior to 1977 (2015)

5.4 Study Methods for Local Drainage Systems

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Historically, the City of Austin has responded to local flooding problems on a case-by-case basis in response to citizen complaints. While complaint information still plays a role in problem prioritization, WPD is moving towards an improved understanding of the magnitude and causes of local flooding, aided by the use of one-dimensional and two-dimensional modeling. Additional tools, including Geographic Information Systems (GIS), offer readily accessible data, as well as an enhanced approach to the measurement of problem severity and the development of solutions. In 2010, WPD began to comprehensively model the capacity of systems in older areas, such as the Central Business District, and other areas with the highest number of recorded flood complaints. In 2012, WPD began to evaluate local flood modeling on a watershed basis, starting with West Bouldin Creek. Section 5.8 discusses this effort in more detail. The long-term goal is to provide models for the rest of the City's storm drain systems on a watershed basis.

5.5 Available Data

WPD uses multiple sources of data to study local drainage problems and solutions. The sources include data from: citizen complaints, GIS, video inspections, field surveys, and one- and two-dimensional storm drain models. Not all of this information is available for a given problem area as discussed below.

5.5.1 Citizen Complaints and Complaint Database

The most longstanding source of data for local flood problems is that of citizen complaint data. WPD began tracking customer drainage complaints in late 1988 through a computer database. It was not until the late 1990s, with the help of GIS, that WPD was able to geographically plot the customer complaints and to begin analyzing the local drainage system. Most of the complaints are gathered today via non-emergency 3-1-1 calls.[1] Each complaint is tracked starting with the physical address of the property reportedly flooded. WPD staff investigate and verify each call to validate the complaint and determine, if possible, the source and severity of the flooding. Flooding sources are classified into two categories: (1) Public and (2) Private. Resolution of private flooding problems is the responsibility of the affected property owners. Resolution of identified public flooding is the purview of the City and is approached as described below.

For public flooding problems, the investigator attempts to confirm the severity of flooding by determining the extent to which the property was affected. Problems considered to be local flooding are typically broken down into three categories as well, in order of highest to lowest concern: (1) Building, (2) Yard, and (3) Street. The investigator also seeks to identify potential remedies, including

[1] Additional complaint information is collected in Neighborhood Plan meetings and other forums, but the preferred method is by 3-1-1 call. This latter method is more systematic and robust.

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examination of the condition of existing infrastructure and research of construction plans. Once a cause has been determined, the complaint is routed to the appropriate work group within WPD. This can be as simple as creating a work order for WPD crews to clear a clogged inlet or it may need to be routed to an engineering group for detailed analysis.

Verified complaint data is entered into a database. This dataset is a useful means of tracking problems experienced by the community. However, this method of tracking local flood problems has two key limitations: uneven reporting and nonspecific data. Not everyone who has experienced local flooding files a complaint. Some are unaware that they can file a complaint. Others may choose not to report for various reasons. Lack of complaint data does not mean that no problem exists.

Complaint data, unlike quantitative modeling data, is also non-specific. Often additional information (e.g., modeling) is needed to determine the full extent of problem severity. Non-specific complaints in the same category (e.g. building, yard, or street) are not necessarily similar in severity, and yet they show up as "one" complaint, thus seemingly equivalent, when presented in maps and tables. However, the density of complaint information is still useful and, in fact, is used to help identify potential solutions to local flooding problems. Figure 5.5-1 shows the location of complaint information by building, yard, and street. Note that building flooding is considered the highest priority since it impacts public safety and living units and creates the highest property damage. Yard flooding is the next highest priority (adjacent to buildings and potentially entering buildings in larger storm events), followed by street flooding (furthest from buildings, although still a concern due to potential hazards for motorists' safety). Table 5.5-1 presents local flood complaints and problem area information by watershed.

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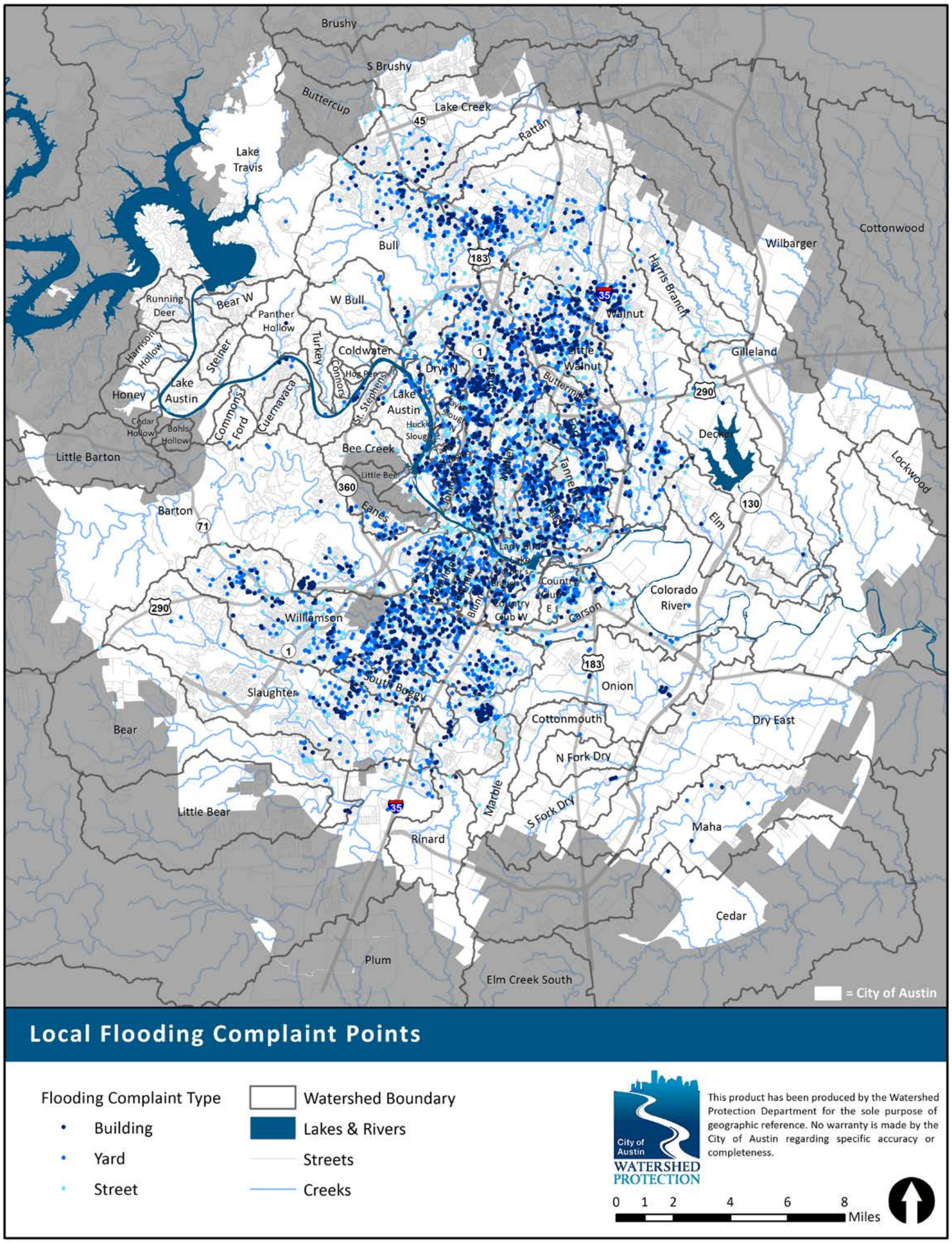

Figure 5.5-1 Location of Local Flood Complaint Points by Building, Yard, & Street (October 2015)

Table 5.5-1 Problem Scores by Watershed: Local Flood Complaint Points and Identified Problem Areas (Oct. 2015)

Watershed	Phase	Number of Properties with Complaints					Identified Problem Areas	
		Count by Flood Code			Total Count	Pct. Total Count	Total Count	Pct. Total Count
		Building	Yard	Street				
Barton	1	73	58	23	154	2.5%	2	1.9%
Bear	2	4	7	8	19	0.3%	0	0.0%
Bee	2	0	1	1	2	0.0%	0	0.0%
Blunn	1	33	35	17	85	1.4%	2	1.9%
Boggy	1	106	149	94	349	5.7%	7	6.8%
Bull	1	64	120	67	251	4.1%	5	4.9%
Buttercup	2	0	0	4	4	0.1%	0	0.0%
Buttermilk	1	12	11	2	25	0.4%	0	0.0%
Carson	2	17	41	35	93	1.5%	2	1.9%
Cedar	2	1	0	0	1	0.0%	0	0.0%
Colorado River	2	11	13	14	38	0.6%	0	0.0%
Commons Ford	2	0	1	0	1	0.0%	0	0.0%
Cottonmouth	2	0	1	0	1	0.0%	0	0.0%
Country Club East	1	10	28	14	52	0.9%	1	1.0%
Country Club West	1	29	28	18	75	1.2%	3	2.9%
Decker	2	2	1	5	8	0.1%	0	0.0%
Dry East	2	0	1	0	1	0.0%	0	0.0%
Dry North	2	16	35	10	61	1.0%	1	1.0%
Eanes	2	9	30	3	42	0.7%	0	0.0%
East Bouldin	1	42	53	24	119	2.0%	2	1.9%
Elm	2	3	1	2	6	0.1%	0	0.0%
Fort Branch	1	78	115	53	246	4.0%	3	2.9%
Gilleland	2	2	5	2	9	0.1%	0	0.0%
Harpers Branch	1	11	12	8	31	0.5%	0	0.0%
Harris Branch	2	3	6	9	18	0.3%	0	0.0%
Huck’s Slough	2	1	5	1	7	0.1%	0	0.0%
Johnson	1	56	74	19	149	2.4%	5	4.9%
Lady Bird Lake	2	88	107	106	301	4.9%	3	2.9%
Lake	2	22	17	12	51	0.8%	0	0.0%
Lake Austin	2	28	42	15	85	1.4%	3	2.9%
Lake Travis	2	0	2	1	3	0.0%	0	0.0%
Little Walnut	1	179	204	96	479	7.9%	7	6.8%
Maha	-	3	3	0	6	0.1%	0	0.0%
Marble	2	0	0	9	9	0.1%	0	0.0%
Onion	2	76	29	22	127	2.1%	0	0.0%
Panther Hollow	2	1	0	0	1	0.0%	0	0.0%

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Table 5.5-1 continued

Watershed	Phase	Number of Properties with Complaints					Identified Problem Areas	
		Count by Flood Code			Total Count	Pct. Total Count	Total Count	Pct. Total Count
		Building	Yard	Street				
Rattan	2	6	11	8	25	0.4%	0	0.0%
Rinard	2	2	0	1	3	0.0%	0	0.0%
Shoal	1	324	278	167	769	12.6%	11	10.7%
Slaughter	2	42	65	29	136	2.2%	0	0.0%
South Boggy	2	44	56	29	129	2.1%	3	2.9%
South Brushy	2	0	0	3	3	0.0%	0	0.0%
South Fork Dry	2	3	0	0	3	0.0%	0	0.0%
St. Stephens	2	0	1	1	2	0.0%	0	0.0%
Tannehill Branch	1	52	78	55	185	3.0%	3	2.9%
Taylor Slough North	2	17	20	19	56	0.9%	1	1.0%
Taylor Slough South	2	23	10	8	41	0.7%	1	1.0%
Waller	1	80	104	85	269	4.4%	5	4.9%
Walnut	1	194	271	101	566	9.3%	17	16.5%
West Bouldin	1	63	63	50	176	2.9%	5	4.9%
West Bull	2	0	5	2	7	0.1%	0	0.0%
Williamson	1	255	398	168	821	13.5%	11	10.7%
Totals:		**2,085**	**2,595**	**1,420**	**6,100**	**100.0%**	**103**	**100.0%**
Maximum Value:		324	398	168	821	13.5%	17	16.5%

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5.5.2 GIS Data

WPD maintains a detailed Geographic Information System (GIS) dataset for the storm drain system. The dataset, called the Drainage Infrastructure GIS (DIG), represents the physical drainage assets owned and maintained by the City of Austin, including storm drain pipes, inlets, culverts, manholes, and ditches. When completed, it will represent not only physical inlets and pipes, but also the related features which connect the physical assets including managed channels, ponds, creeks, and other features. This project, which is further explained in Section 8.3, is scheduled for completion in 2017. Figure 5.5-2 below shows a subset of the DIG data available in a portion of the West Bouldin watershed.

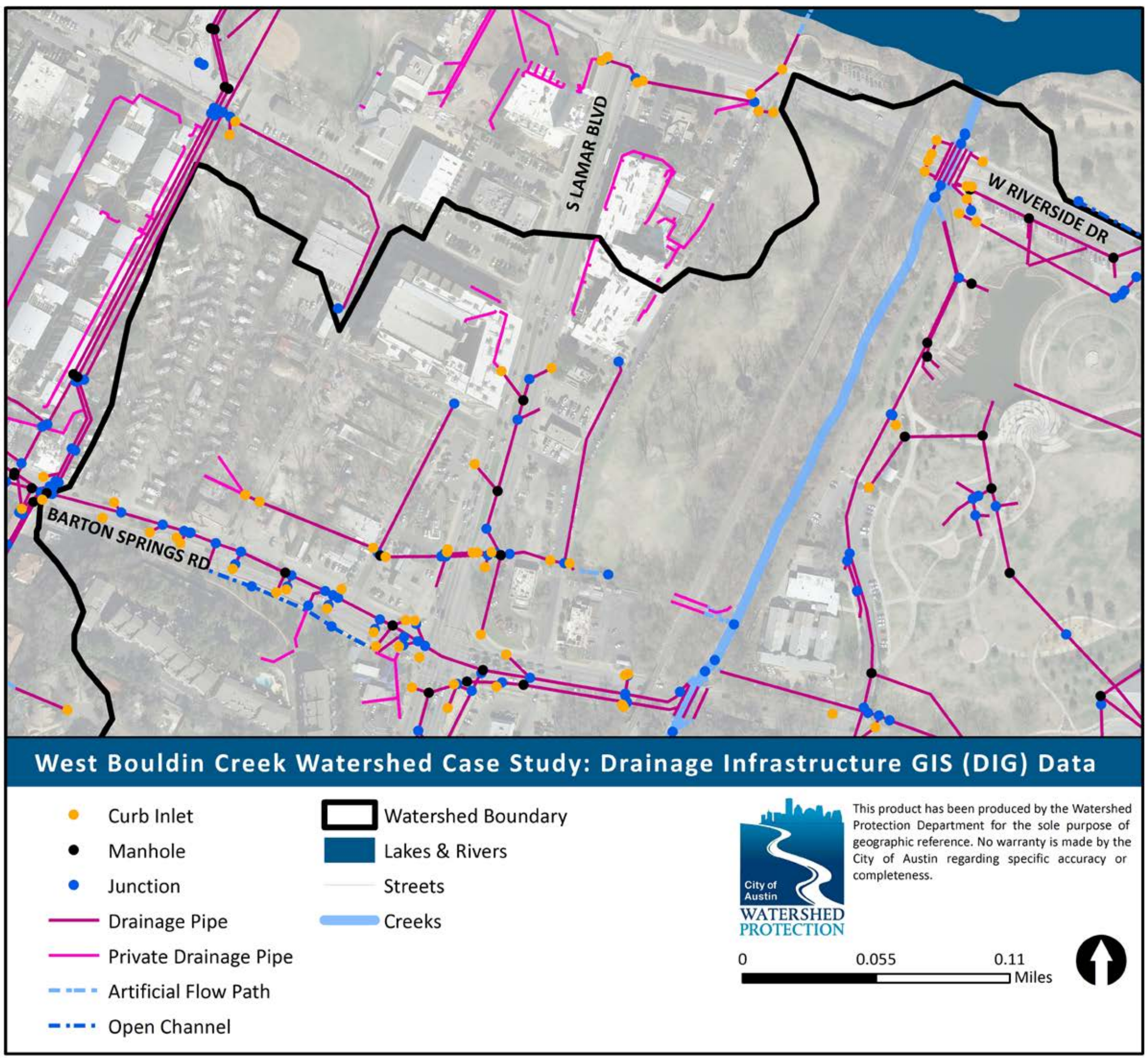

Figure 5.5-2 Drainage Infrastructure GIS (DIG) Data for a Sample Portion of the West Bouldin Watershed. These features represent a small subset of the available DIG data. (2015)

5.5.3 Video Inspections

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The City currently has two video inspection crews on staff and contracts with an independent contractor to collect additional video footage of storm drain systems. This work identifies blockages or sections of pipe needing structural repairs. During pipe inspections, video crews score the condition of the pipe system using NASSCI Pipeline Assessment Certification Program standards to rate their condition and need for maintenance. This data is currently only available for the Central Business District and some other limited study areas. Data gathering is ongoing and the crews complete about 12.5 miles of video inspection per year. Figure 5.5-3 shows a photo of the equipment used to acquire the video information.

Figure 5.5-3 TV Inspection Equipment (2015)

5.5.4 1-D and 2-D Storm Drain Models

WPD uses one-dimensional (1-D) storm drain modeling software to simulate storm events and assess the ability of existing storm drain systems to capture and convey runoff. This can be done for the regulated storm scenarios (e.g., 2-, 10-, 25-, and 100-year storm events) and with a variety of land use conditions to evaluate the level of service provided by storm drain systems. Modeling staff typically assume the maximum impervious coverage allowed by zoning to account for potential future increases in land use intensity (i.e. development). GIS data provides key information used to build hydrologic and hydraulic models to estimate drainage capacity. These analyses allow staff to determine which systems fail to meet the City's current design criteria and to evaluate alternatives for system improvement. These models identify pipe capacity: the "one dimension" is that of vertical elevation. The models show, for given storm events (e.g., the 2-year 24-hour event, etc.), how capable each component of the storm drain systems are at containing the hydraulic gradient lines (HGL, effectively the water surface elevation) within the conduit system. Once a given storm size shows the HGL rising above the ground surface level, the piped system can be assumed to have exceeded capacity. Thus the system can be said to, if applicable, fail to pass the 2- or the 10-year storm event and so forth. This is key information: current Code requires containment of the prescribed **25-year, 24-hour storm** within one foot below the theoretical gutter elevation. However, the one dimensional models are not able to predict the flow patterns of water above ground surface elevations. Figure 5.5-4 shows an example analysis for the West Bouldin watershed storm drain system in South Austin. Some systems in this sample study area fail in a 2-year storm event, others in the 10-year event.

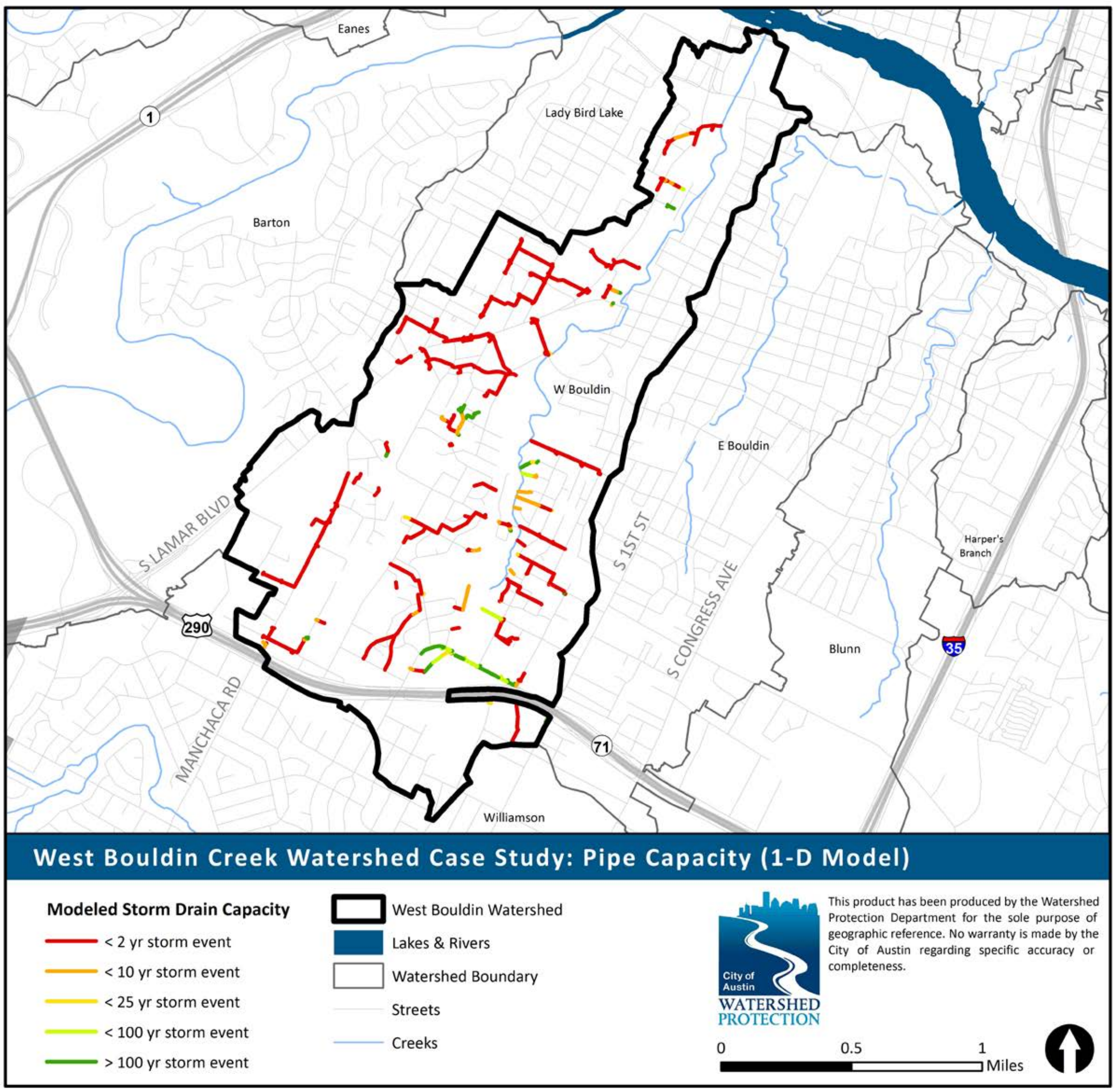

Figure 5.5-4 Example Use of 1-D Models to Estimate System Capacity (2015)

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At the time of this writing, 1-D models have been completed for over 477 miles of the City's systems. This represents about 43% of the approximately 1,100 miles of storm drain pipe in the City. The long-term plan is to conduct these analyses for all systems. Figure 5.5-5 below shows the areas of town with complete and in-progress 1-D models.

Shortly before 2014, WPD began to evaluate the use of two-dimensional (2-D) models to identify flooding impacts where drainage systems fail. This approach provides a more detailed estimation of the impacts on public and private property when the storm drain system is undersized. Two-dimensional models estimate not only the HGL elevation but also the spread of water on the surface, thereby showing which structures and roadways may be affected. But the detailed 2-D modeling process is very labor-intensive and typically more time consuming to produce when compared to 1-D models. When available, the results of these 2-D models greatly improve the understanding of problem areas and are useful in designing projects to protect lives and property during flood conditions.

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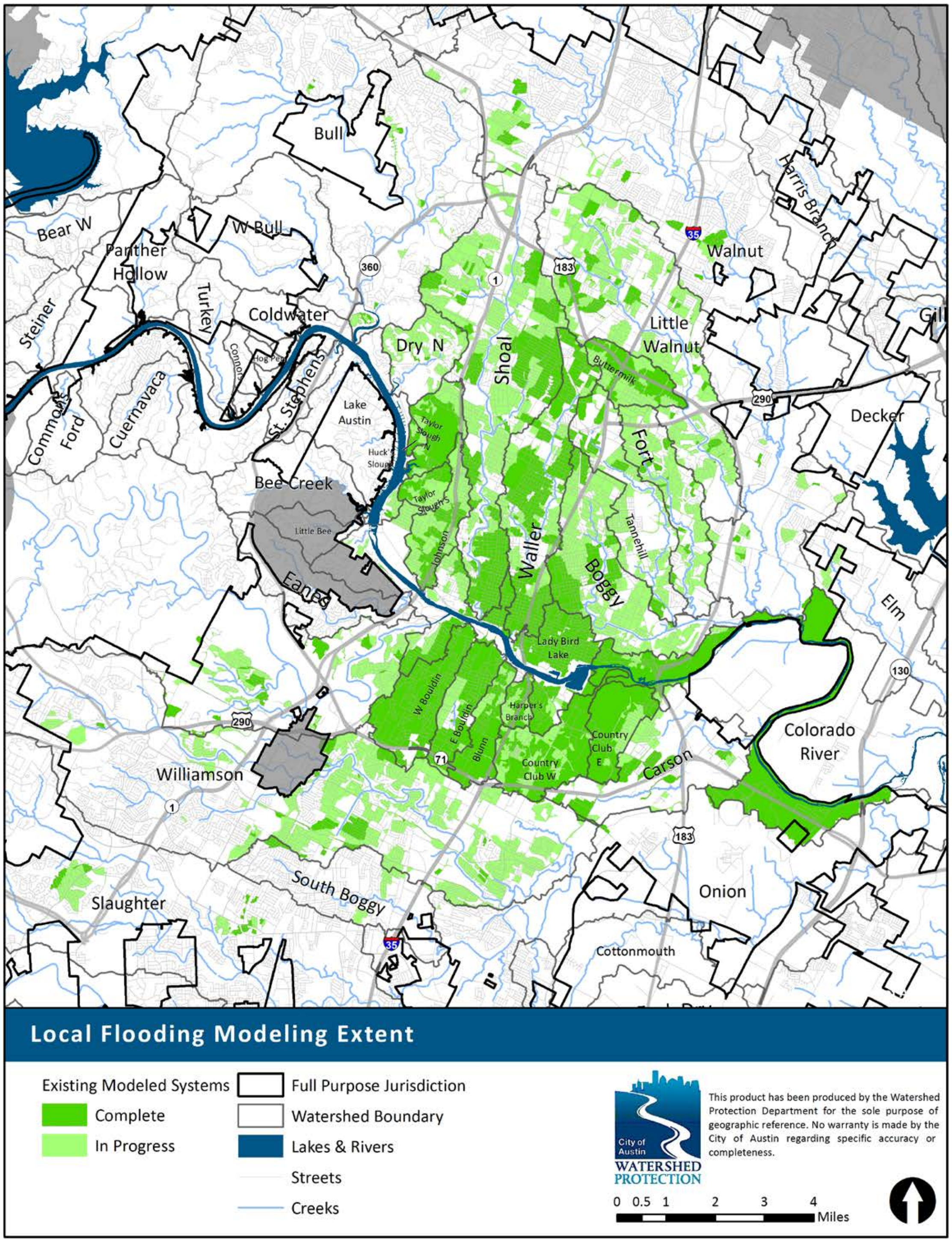

Figure 5.5-5 Local Flood Modeling Extent (2015)

5.6 Local Flood Problem Prioritization

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Local flood problems are currently prioritized using citizen complaint data. This process is completed annually and uses the complaint database to aggregate flooding complaints. The data is first checked (e.g., to remove duplicate addresses) and potential project areas are identified where problem area “clusters” of five or more complaint points are located within 150 feet of each other. In cases where there is more than one complaint at the same address, only the most severe complaint is counted. Figures 5.6-1 shows the steps of this process with an example of complaints, point buffering, and the resulting complaint clusters.

Each cluster is assigned a rank determined by the number and type of complaints. Building complaints are given the highest priority, and then clusters with the same number of building complaints are ranked by number of total complaints (building, yard, and street flooding complaints). Each cluster can be ranked against all others using this sorting methodology. The cluster information is then used to create Local Flood Problem Area boundaries delineating the approximate drainage area around the highest-ranked complaint clusters. Figure 5.7-1 shows a map of the identified Local Flood Problem Areas. These new Problem Areas are then ranked by the total number and type of complaints within the entire drainage area. The results of this ranking are displayed in Table 5.7-1, which shows the Top 20 Problem Areas by number of complaints. 2D modeling scores are not currently available for these problem areas, but this information will be incorporated into problem scores in a future update. This problem score ranking is used to identify potential project solutions for completion via future capital improvement projects (see Section 10).

In the future, WPD plans to develop engineering models for all local drainage systems within the City’s corporate limits and use the resulting analysis to prioritize problem areas. This will provide uniform and objective data and address the concerns cited above about the uneven and unspecific nature of citizen complaint data. However, the modeling of 1,100 miles of storm drainage systems is a major undertaking and will require several years to prepare models for all city storm drain systems.

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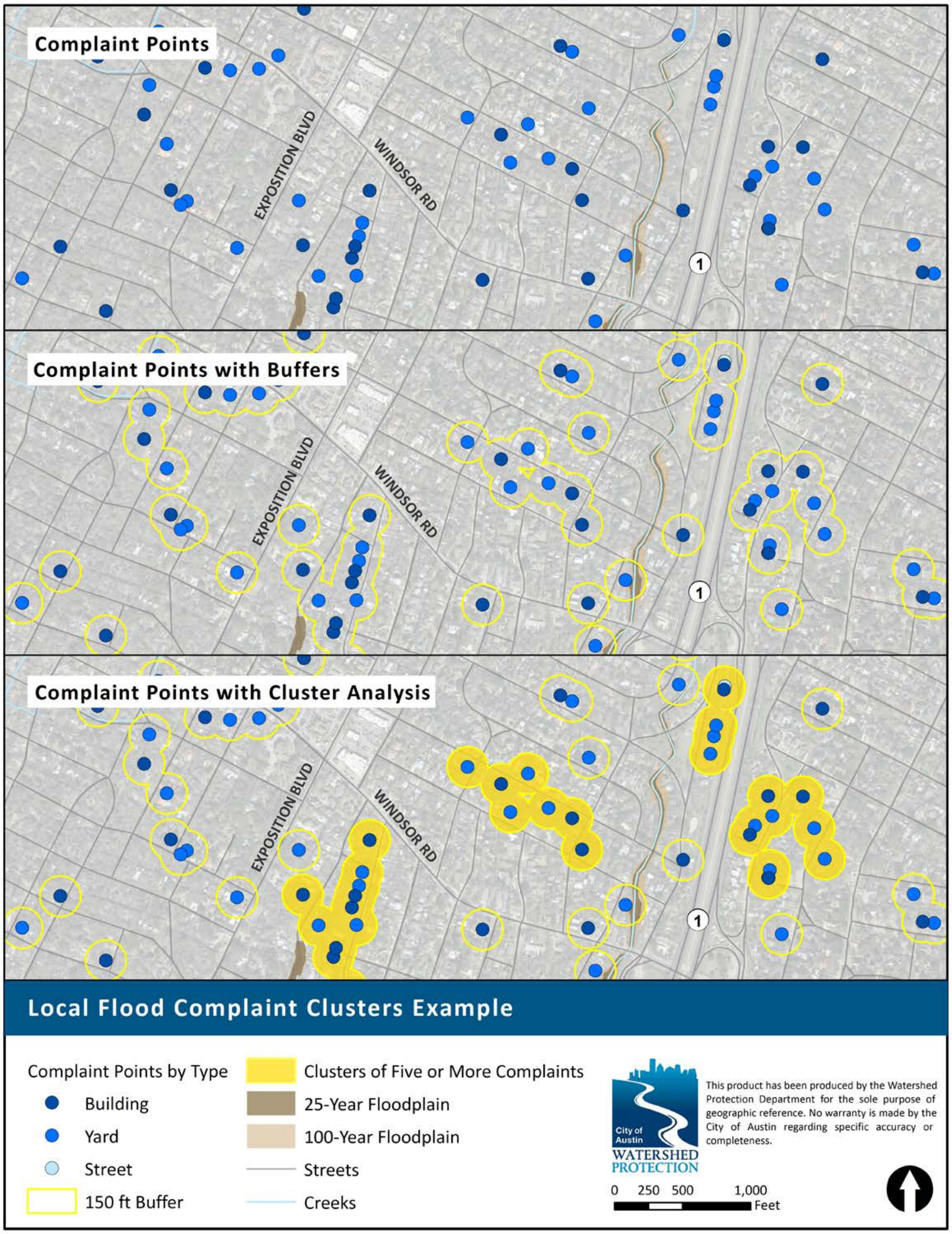

Figure 5.6-1 Example of the Development of Clusters of Five or More Complaints. The floodplain boundary represents the City of Austin's fully developed regulatory floodplain. (2015)

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5.7 Results

Figure 5.7-1 shows a map of the identified Local Flood Problem Areas resulting from the prioritization process described above. Unsurprisingly, many of these Local Flood Problem Areas are located in Austin's central core, where outdated drainage infrastructure built prior to 1977 predominates. Referring back to Figure 5.5-1, which presents the number of local flood complaints and problem areas by watershed, just over 29% of Identified Problem Areas are located in Shoal, Boggy, Little Walnut, and Johnson Creek watersheds alone. The largest number of complaints and Problem Areas, however, are actually found in larger Suburban watersheds that have seen extensive development since the creation of WPD's regulatory distinctions. Walnut Creek, which is considered a Suburban watershed for regulatory purposes, has the highest number of Problem Areas with 17, representing 16.5% of all Problem Areas. Because the majority of these problem areas are located in recently-annexed portions of the city, the drainage infrastructure was not constructed according to the Drainage Criteria Manual. Similarly, Williamson Creek watershed has the highest number of citizen complaints with 821, representing over 13% of total complaints.

The Problem Areas displayed in Figure 5.7-1 are subsequently ranked by the total number and type of complaints within the entire drainage area. This ranking is used to quantify the relative priority of Local Flood concerns throughout the City of Austin. The results of this ranking are displayed in Table 5.7-1, which shows the Top 20 Problem Areas by watershed and number of building, yard, and street complaints. Again, the majority of the highest ranking problem areas are those in the urban core, where the majority of development occurred prior to the advent of modern engineering criteria; 12 of the Top 20 Problem Areas are located within Urban watersheds. One notable exception to this pattern is Oak Acres in the Barton Creek watershed, which is the highest ranked Problem Area with 49 building complaints. Section 10 presents the methodology by which problem areas are prioritized for solution implementation, which considers not only the problem severity but also other factors, such as cost and technical feasibility. See Tables 10.3-1 through 10.3-5 for the Top 20 Priority Problem Areas.

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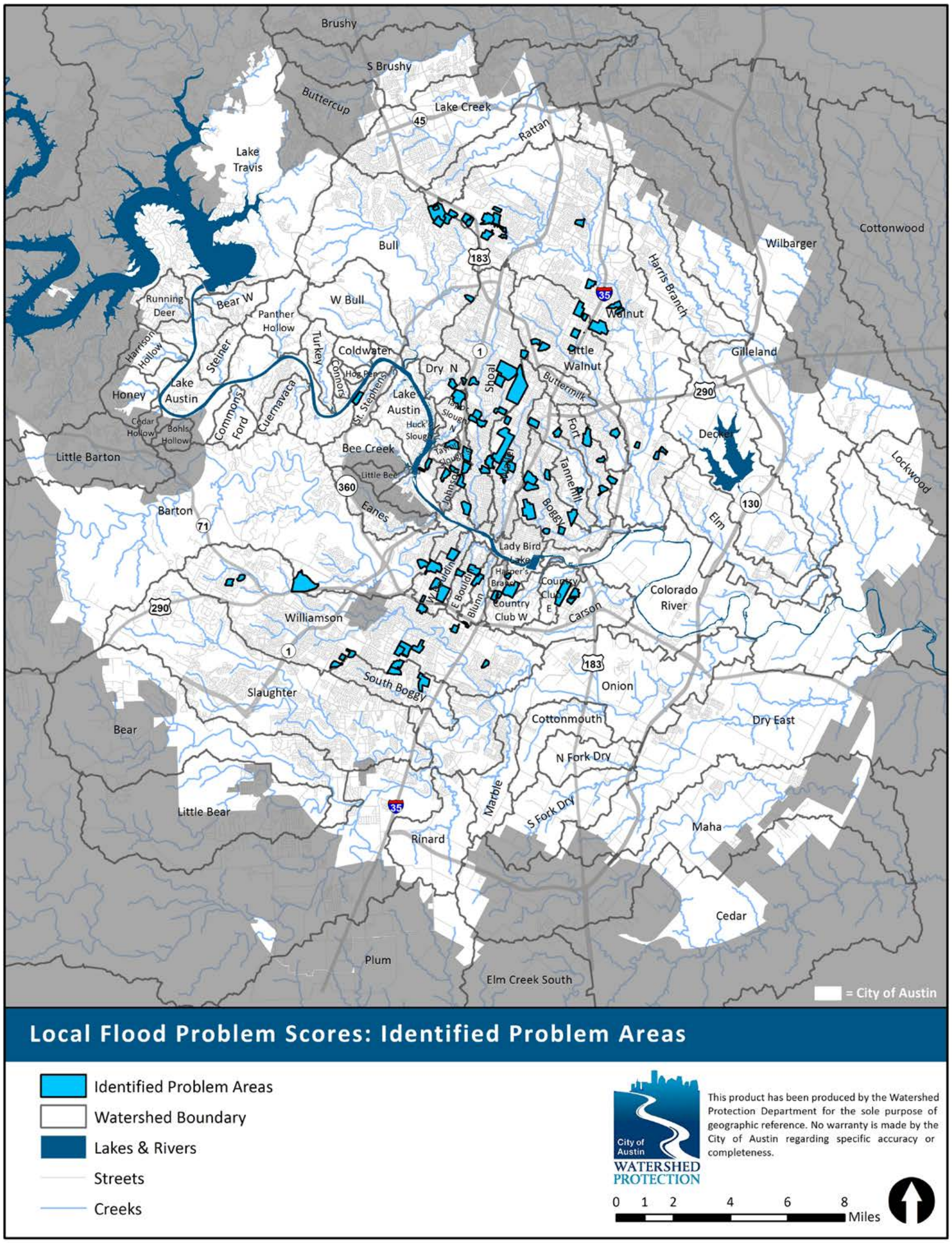

Figure 5.7-1 Identified Local Flood Problem Areas used to Prioritize Potential Capital Improvement Projects (October 2015)

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Table 5.7-1 Top 20 Ranked Problem Scores: Local Flood Problem Areas (October 2015)

Rank	Problem Area Name	Watershed	Number of Complaints			
			Building	Yard	Street	Total
1	Oak Acres	Barton	49	7	5	61
2	Brentwood St	Shoal	31	26	12	69
3	West Cow Path	Walnut	15	13	1	29
4	Guadalupe St	Waller	15	10	14	39
5	Warren St	Taylor Slough South	14	0	3	17
6	Annie St	East Bouldin	13	3	1	17
7	January Dr	Walnut	13	0	1	14
8	Briar Hill Dr	Lady Bird Lake	11	3	4	18
9	Madison Ave	Shoal	10	9	3	22
10	Oakmont Blvd	Johnson	10	7	2	19
11	Oak Knoll	Walnut	10	5	0	15
12	Hollywood Ave/Group 21	Boggy	9	11	1	21
13	Hancock Dr	Taylor Slough North	9	8	2	19
14	North Acres	Walnut	9	6	1	16
15	Bullard Dr	Shoal	9	6	0	15
16	Oriole Dr	Little Walnut	9	5	0	14
17	Del Curto Rd	West Bouldin	8	7	2	17
18	Stamford Ln	Johnson	8	6	2	16
19	Jamestown Dr	Little Walnut	7	11	0	18
20	Natrona Dr	Walnut	7	4	1	12

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5.8 Intensive Study of West Bouldin Watershed – Case Study

Austin is one of the fastest growing cities in the United States. Much of this explosive growth is happening in the form of infill redevelopment in the urban core—precisely the location of the oldest and most undersized storm drain systems. WPD has responded to this challenge with many new strategies. One key initiative, initiated in 2012, is an intensive planning study to assess existing drainage systems in the West Bouldin watershed, located just south of Lady Bird Lake and at the epicenter of this infill development along South Lamar Boulevard. At the time West Bouldin was chosen for this study, it had the highest number of site plan permits (from 2010 to 2012) of any Austin zip code. The objective was to identify system deficiencies and explore potential improvements. Figure 5.8-1 shows the areas of critical flooding studied. These problem areas often coincide with areas where land development projects are being planned or are already under construction.

This study serves as a pilot study. WPD will evaluate whether additional watersheds should be approached in a similarly focused manner. Future updates of this Master Plan will report on its findings and practicality for citywide application.

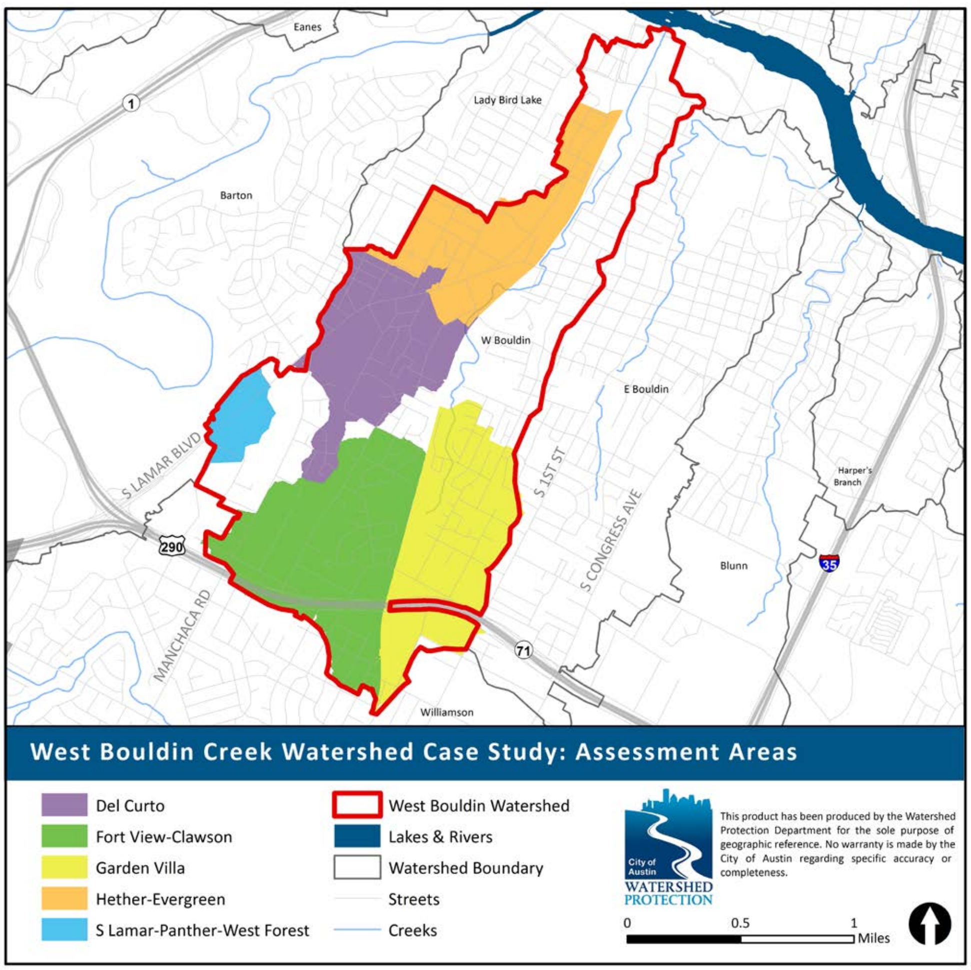

Figure 5.8-1 Map of Local Drainage System Assessment Areas in West Bouldin Watershed Case Study (2015)

6 Erosion Assessment

6.1 Background

Many of Austin's watersheds (including both urban and suburban watersheds) are drained by streams that exhibit stream erosion. Erosion problems can stem from changing land use conditions (i.e. urbanization) that modify watershed hydrology by increasing stormwater runoff. Other problems occur due to improper placement of man-made resources near stream banks. Changes in streamflow have resulted in accelerated changes in local creek characteristics. For example, past geodetic survey data shows that a typical section of Boggy Creek has expanded by 30 feet and deepened by 6 feet over a 25 year period, as shown in Figure 6.1-1. As stream channels react to changes in watershed hydrology, concerns arise regarding future creek bank failures, the resulting impacts to creekside resources, long-term channel degradation, and water quality. To help identify these concerns, WPD staff conduct detailed erosion assessments for Austin's major creeks.

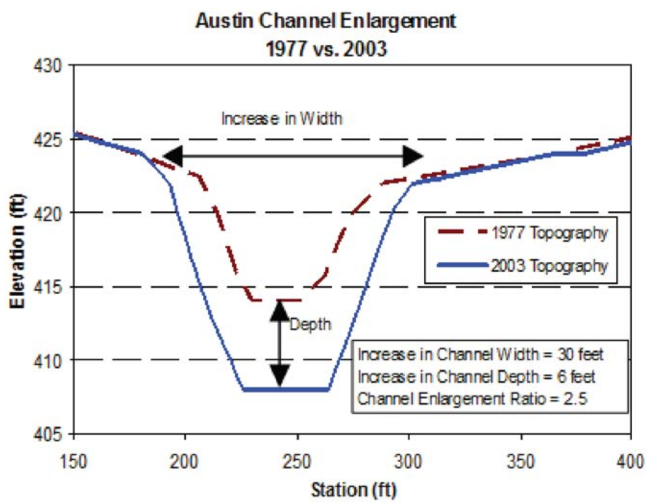

Figure 6.1-1 Boggy Creek Channel Enlargement: 1977 vs. 2003

6.2 Overview of Assessment Methodology

Section 6 describes the methods used to investigate problems associated with stream channel erosion. The methodology takes erosion information collected from field studies, ranks problems by severity, and proposes a list of Top 20 problem areas. Solutions to these problems are discussed in Section 10.

Figure 6.2-1 graphically presents the methodology for erosion.

1. **Collect Field Data.** Individual erosion site and geomorphic reach assessment data are collected in field.

2. **Generate Problem Scores.** Site and reach assessment data are combined into problem scores representing overall erosion severity by geomorphic reach. Scores are normalized on a 100-point scale. The higher the score, the more severe the problem. Normalized scores are assigned a narrative rating of Very High to Very Low. The 20 highest scoring (ranking) reaches are identified.

3. **Prioritize Problems for CIP Solution Integration.** High ranking problem reaches are further evaluated for site-specific feasibility considerations. Section 10 discusses how projects are developed and prioritized from priority problem areas.

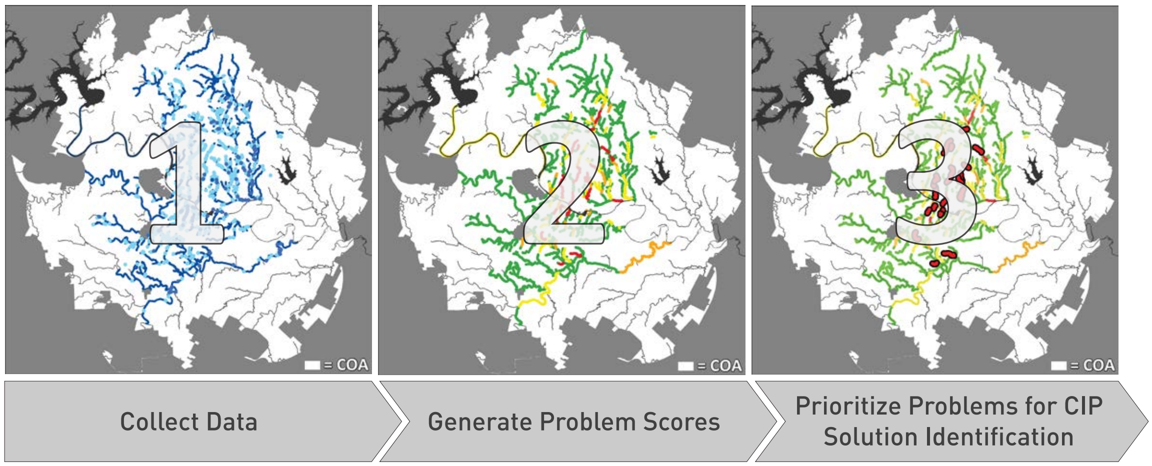

Figure 6.2-1 Erosion Prioritization Methodology (2015). Steps 1 & 2 are described here in Section 6, while Step 3 is described in Section 10.

6.3 Study Methods

Study methods recommended for conducting erosion assessments in the City of Austin were first described in a report entitled Technical Procedures for the Watershed Erosion Assessments (Raymond Chan and Associates, 1997). This report was developed to serve as a guide for individual watershed studies. The report helped document and standardize the procedures to be used to assess and describe watershed conditions, the types of data to be collected, and the subsequent evaluations to be performed. Additional refinements and improvements have been made to the approach since 1997.

The goal of a Watershed Erosion Assessment is to characterize general creek conditions, identify current erosion problems along the creek system, and to garner a better understanding of where future problems may occur. An inventory of problem erosion sites is produced identifying locations along the creeks where erosion poses an existing or future threat to property, stream stability, water quality, utilities, and drainage infrastructure. The initial 1997 Erosion Assessments included field investigations on the main branches of the 18 Phase 1 creeks and tributaries up to a contributing drainage area threshold of 640 acres (one square mile). This resulted in an inventory of over 170 miles of stream channels. Numerous photographs and stream cross-section measurements were taken, generating a photographic log that will serve as a stream benchmark – allowing future comparisons to be made with documented stream conditions. Since the initial Phase 1 Erosion Assessments, additional Erosion Assessments have been carried out in eight Phase 2 watersheds. Targeted investigations have also been carried out at individual erosion sites in unassessed reaches identified in response to citizen complaints and staff reconnaissance.

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Additional Erosion Assessments for unassessed watersheds are planned based on future development potential, proximity to existing watersheds with assessments, and those with known erosion sites (see Table 6.3-1 below). In total, 26 watersheds have been assessed as of this present update.

Table 6.3-1 Summary of Erosion Studies

Watersheds with Completed Erosion Assessments				Future Planned Assessments	
1.	Barton	14.	Harpers Branch	27.	Bear
2.	Blunn	15.	Harris Branch*	28.	Dry Creek North
3.	Boggy	16.	Johnson	29.	Lake
4.	Bull	17.	Little Walnut	30.	Little Bear
5.	Buttermilk	18.	Onion	31.	Rattan
6.	Carson	19.	Shoal	32.	South Brushy
7.	Country Club East	20.	Slaughter	33.	Taylor Slough North
8.	Country Club West	21.	South Boggy	34.	Taylor Slough South
9.	Decker*	22.	Tannehill Branch		
10.	East Bouldin	23.	Waller		
11.	Elm*	24.	Walnut		
12.	Fort Branch	25.	West Bouldin		
13.	Gilleland*	26.	Williamson		

** No problem score data available at present except for two Gilleland reaches; scores be included in a future update.*

6.3.1 Erosion Problem Site Identification

Figure 6.3-1 Example of Streambank Erosion

During field surveys, existing erosion problems are noted where physical structures or other community resources are threatened or have the potential to be threatened in the future. Structures of interest include houses, buildings, parking lots, bridges, retaining walls, trees, utility poles and utilities crossing the creek, and fences. Field teams also note areas where a significant loss of land may occur as a result of a bank failure or where steep creek banks within park areas pose a safety threat to the public. An example eroding streambank is shown in Figure 6.3-1. Erosion problem sites are categorized as shown in Table 6.3-2. Figure 6.3-2 shows an example Type 1 problem: a threatened structure.

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Table 6.3-2 Erosion Problem Example

Priority	Description
Type 1	Imminent threat to a habitable structure or roadway
Type 2	Current threat to other resources (walls, fences, trees, trails, utility lines, yards, or recreational amenities)
Type 3	Potential future threat (active erosion)

In the Phase 1 Watershed Erosion Assessments, approximately 975 erosion problems were identified. The erosion site database currently (Oct. 2015) includes approximately 1,130 active erosion sites. Despite over 13 years of implementation of stream stabilization projects, the number of erosion problems continues to increase due to perpetual changes in the stream system; continued identification of additional erosion problems on smaller, previously unassessed tributaries; and the identification of problems in watersheds in which assessments have not been completed.

Figure 6.3-2 Type 1 Erosion Example

The resulting inventory of erosion problems identified during the Erosion Assessments and additional investigations is later used to help prioritize erosion problem areas (see Section 6.5, Erosion Scoring System, and Section 6.6, Erosion Site Severity).

6.3.2 Stream Reach Classification System

A stream reach classification system is applied to classify "geomorphically similar" or "like" reaches. In simple terms, field investigation crews determined where continuous lengths of creeks demonstrate similar channel characteristics based on channel type. The original Phase 1 Erosion Assessments identified and assessed 199 reaches. Today, the erosion database includes over 480 reaches, including those identified from Phase 2 Erosion Assessment studies of Onion, Carson, Slaughter, Decker, Elm, Gilleland, Harris Branch, and South Boggy Creeks, as well as additional reaches where investigations have been initiated by citizen complaints and staff reconnaissance. The designated channel types are categorized in Table 6.3-3 below.

Table 6.3-3 Stream Reach Classifications

Channel Types	Typical Channel Description	Relative Susceptibility to Erosion
Alluvial	Formed in alluvium (loose gravel, sand or silt) or unconsolidated overburden deposits - susceptible to scour.	High
Rock Bed	Channel is worn into massive bedrock materials or well armored with scour resistant materials. One or both banks are formed in alluvial or unconsolidated soils - susceptible to erosion.	Moderate
Rock Controlled	Channels are commonly formed in bedrock materials with the banks being relatively resistant to erosion scour.	Low
Structurally Controlled	Channel has been modified and armored with concrete rip rap, rock gabions, stone, etc.	Varies

Source: Raymond Chan & Associates, 1997.

6.3.3 Stream Stability Ratings

After the identification of "like" reaches based on the channel types listed above, field teams complete a rapid geomorphic assessment (RGA) of each reach to determine the relative stability of the creek channel system. By observing the presence of various physical features within a reach, field crews characterize channel stability based on visual evidence of ongoing erosional processes (widening, downcutting, degradation, and aggradation). Reaches are then categorized into one of three stability classes as shown in Table 6.3-4:

Table 6.3-4 Stability Classes

Stability Class	Description
Stable	Little to no evidence of channel instability or enlargement. The stream channel is conveying water and sediment loads without substantial erosion or deposition.
In Transition	Frequent evidence of instability leading to channel enlargement. Increased runoff is exceeding the ability of the natural channel to maintain its form.
In Adjustment	Widespread evidence of channel instability and channel enlargement. Channel has been significantly destabilized and is attempting to adapt to large, rapid changes in the water and sediment loads delivered to the stream system.

Table 6.3-5 shows the stability ratings for Phase 1 and 2 watersheds for which stability ratings are available. While stability ratings are not incorporated into the erosion scoring system, they represent important information about the overall condition of the channel. The stability rating indicates the current condition of the channel and the past erosion features observed in the field.

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The stability rating is also used to determine the expected processes that may cause or accelerate channel enlargement in the future. The majority of stable channels are located in rock controlled or structurally controlled reaches. Of the watersheds with stability ratings, Barton Creek had the highest percentage (90%) of its reaches in "stable" condition. Just over half of the reaches are considered to be "in transition," demonstrating the effects of urbanization on stream channels. East Bouldin Creek had the highest percentage (nearly 94%) of its reaches "in transition." Just over one-fourth of the creek reaches were determined to be "in adjustment," demonstrating significant evidence of channel instability and enlargement. It is not surprising that many of the reaches that are in adjustment are located in alluvial channels where the upstream contributing drainage area has experienced significant urbanization.

Table 6.3-5 Phase 1 and 2 Watershed Stream Reaches by Stability Class (2015)

Watershed	Phase	Number of Stream Reaches			
		Stable	In Transition	In Adjustment	Total
Barton	1	9	1	0	10
Blunn	1	0	2	3	5
Boggy	1	1	3	3	7
Bull	1	2	14	5	21
Buttermilk	1	0	5	1	6
Carson	2	8	11	10	29
Country Club East	1	1	1	1	3
Country Club West	1	0	0	5	5
East Bouldin	1	1	15	0	16
Fort Branch	1	3	5	5	13
Harpers Branch	1	4	2	0	6
Johnson	1	5	4	1	10
Little Walnut	1	1	15	1	17
Onion	2	0	3	7	10
Shoal	1	3	11	7	21
Slaughter	2	2	2	0	4
South Boggy	2	2	6	0	8
Tannehill Branch	1	2	5	1	8
Waller	1	4	6	2	12
Walnut	1	6	22	7	35
West Bouldin	1	1	2	2	5
Williamson	1	4	8	7	19
Total		**59**	**143**	**68**	**270**

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6.4 Resource Values

As stream erosion progresses, it has the potential to affect numerous community resources. As discussed in Section 3.2, the prioritization methods used for each WPD mission rely, in part, on the assignment of "values" to each community resource threatened by erosion, flooding, and water quality degradation. During the stream field inventory, existing and potential erosion threats to property are documented.

To describe the various kinds of resources threatened by erosion, resource types are identified for all erosion sites. For prioritization purposes, resource values on a 0 to 100 scale (100 being highest/ most valued) are assigned to each resource type to give a relative weight for an impact to that resource. Table 6.4-1 presents the resource values.

Table 6.4-1 Erosion Control Resource Values

Resource Type	Resource Value	Resource Type	Resource Value
House	100	Hike and Bike Trail	70
Building	100	Golf Course	50
Mobile Home	90	Pedestrian Bridge	70
Major Road	100	Heritage Tree	70
Minor Road	75	Protected Tree	35
Public Sidewalk	50	Priority Woodland (Public)	25
Bridge	100	Priority Woodland (Private)	10
Culvert	70	Woodland	5
Low Water Crossing	70	Agricultural Land/Farm	15
Garage	70	Manhole	45
Fixed Storage Building	50	Pipeline	45
Deck	45	Stormdrain Pipe	45
Patio	25	Wastewater Pipe	45
Driveway	50	Water Pipe	45
Fence	30	Gas Pipe	45
Yard (major loss)	35	Utility Line	45
Retaining Wall	50	Utility Pole	45
Dam	50	Concrete Riprap Slope Protection	10
Grade Control	35	Concrete Flume	35
Parking Lot	50	Railroad Bridge	75
Public Recreational Amenity	70	Railroad	75
Parkland	70	Railroad Bridge - Capital Metro	75
Swimming Pool	70	Railroad - Capital Metro	75

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The resource values shown above are used in the development of problem area scores as discussed later in Section 6.5. In addition to resource values, an "owner" responsibility designation is included to denote where the WPD considers the erosion problem to be the owner's responsibility. In these cases, an erosion severity score is calculated; however, it is not used in the prioritization of drainage utility funded projects. Resources tagged with these other responsibility designations include the following:

- Resources that are **not directly impacted by creek erosion** or discharges from City drainage infrastructure (e.g., impacts from hillside erosion processes; site runoff from rooftops, yards, or parking lots; structural impacts not related to creek erosion);
- **Private amenities encroaching the floodplain or channel**
- **Resources improperly located by a property owner where active erosion was evident** at the time of construction/installation (e.g., owner-located structure near the top of an actively eroding creek bank); and
- Other resources for which maintenance is considered the responsibility of the owner, another municipality, county, state or other City department (e.g., state bridges, private dams, and utility lines).

6.5 Erosion Scoring System

Erosion problem scores are calculated using quantitative site data rather than subjective assessments based on visual observations. This approach can be performed efficiently using WPD staff. While subjective assessments represent useful reference information for reaches as a whole, quantitative site-specific data provide a practical and sound basis for objectively evaluating relative erosion problem priority on a citywide scale.

Erosion problems scores are developed for individual erosion sites and for stream reaches (ECx). The reach erosion problem score is calculated as the summation of the erosion site problem scores within a given geomorphic reach as represented with the following formula:

$$\mathbf{EC_{Reach} = \sum_{i=1}^{n} {}_{(ECSite)i}}$$

Where:

EC_{Reach}	= Reach erosion problem score
EC_{Site}	= Erosion site problem score
n	= Number of erosion sites within a reach

The erosion site problem score is described as the product of the erosion site severity score and the assigned resource value of the threatened feature:

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$$EC_{Site} = RV*ES$$

Where:

EC_{Site} = Erosion site problem score
RV = Resource value associated with threatened feature
ES = Erosion site severity score for individual erosion sites

With this approach, the erosion Type 1, 2, or 3 designation (defined in Table 6.3-2 above) is not included in the calculation, but rather is a descriptor based on the erosion severity and the resource type.

6.6 Erosion Site Severity

The erosion site severity score (ES) describes the relative level of threat to a resource based on its proximity to the stream bank, the potential for progression of the problem, and the inferred consequence of slope failure. The erosion severity score reflects the geotechnical conditions affecting slope stability of the stream bank; the surface cover resistance provided by vegetation or armoring; and the geomorphic planform (i.e., stream meandering) influences affecting stream stability at the erosion site location. Key information in the erosion severity score is distance of the resource from the stream bank, the height of the stream bank, the stream bank angle, soil type, percentage of surface cover on the bank (e.g., vegetation, root mass, debris, or armoring), and resource location relative to bends in the stream pattern. The erosion site severity score is computed as a weighted distribution of geotechnical, surface cover, and planform influence:

ES = Geotechnical Score*Wg + Surface Cover Score*Wv + Planform Score*Wp

Where:

ES = Erosion site severity score for individual erosion sites
Geotechnical Score = Score for geotechnical stability of the bank
Surface Cover Score = Score for the amount of vegetation cover on the bank
Planform Score = Score for location relative to stream meanders
Wg = Weighting factor for geotechnical score
Wv = Weighting factor for surface cover score
Wp = Weighting factor for planform score

Each of these three component scores is described below. All three factors are important and are given equal weighting: one-third for each scoring component.

6.6.1 Geotechnical Score

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The geotechnical score is based on an expression of slope stability of the creek bank as it relates to the threatened resource. A resource is considered "threatened" when the stability of the supporting soils around is insufficient. For purposes of relative scoring, bank stability is then evaluated at the critical point where the resource would first become threatened. The "resource critical slope" is identified as the projection from the toe of the creek bank to the edge of the resource as shown in Figure 6.6-1.

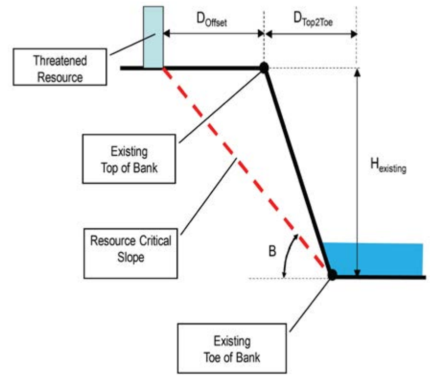

Figure 6.6-1 Geotechnical Stability Expression for Erosion Severity Score

Stability of the resource critical slope can reasonably be expressed using a planar failure analysis model. For this purpose, Culmann's limit equilibrium method is used to predict the maximum bank height for which critical equilibrium occurs with the following formula:

Hc = 4*c/gamma*[sin(B)*cos(phi)/(1 – cos(B - phi))]

Where:

Hc	= Critical bank height (ft)
c	= Bank material cohesion (lb/ft2)
gamma	= Unit weight of bank material (lb/ft3)
phi	= Bank material internal friction angle (degrees)
B	= Critical resource slope angle (degrees)

For use in erosion site severity scoring, the critical resource slope angle is used as the bank angle (B) in Culmann's method. The soil within the wedge between the resource and the existing top of bank is discounted because it is seen as inconsequential prior to the resource becoming geotechnically "threatened." This material is susceptible to removal from intermittent sliding and fluvial action prior to directly impacting the resource and therefore is considered sacrificial. The resource critical slope angle is calculated as:

B = Tan-1 [Hexisting/(Doffset + DTop2Toe)]

Where:

B	= Critical resource slope angle (degrees)
$H_{existing}$	= Existing bank Height (ft)
D_{offset}	= Horizontal distance from existing top of bank to threatened resource (ft)
$D_{Top2Toe}$	= Horizontal distance between the top of bank and toe of bank (ft)

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Application of Culmann's method includes soil properties of unit weight, angle of internal friction, and cohesion. Due to practical limitations of acquiring detailed site-specific laboratory soil data at all known erosion sites, assumed values based on general descriptions of bank composition are applied. Bed and bank material composition can be classified as either alluvial, composite, or rock for all known erosion sites. To provide a relative indicator of soil strength between the bank type categories, the following soil properties in Table 6.6-1 are assumed:

Table 6.6-1 Assumed Bank Material Properties for Geotechnical Score

Bank Material	Phi: Internal Angle of Friction	C: Cohesion (lb/ft^2)	Gamma: Dry Unit Weight of soil (lb/ft^3)
Alluvial	18	50	120
Composite	22	275	125
Rock	30	500	130

The geotechnical score is then computed as the ratio of the existing bank height to the critical bank height (H/Hc) using Cullman's method multiplied by a geotechnical normalization factor (GTNF):

Geotechnical Score = H/Hc (GTNF)

The GTNF normalization factor is used so that the maximum geotechnical score of all sites within the erosion database does not exceed a value of 100. GTNF is calculated as 100 divided by the maximum value of H/Hc within the erosion site database. The ratio of bank height to critical bank height (H/Hc) is also used to designate whether a site has the Type 1, 2, or 3 erosion site rating. When H/Hc is greater than the erosion site type factor (ESTF) the resource is considered "threatened." When H/Hc > ESTF and the resource is a public roadway or habitable structure, then the site is considered to be Type 1. When the H/Hc > ESTF for all other resources, then the site is designated as a Type 2. When H/Hc < ESTF, then the site is designated as Type 3.

6.6.2 Surface Cover Score

The surface cover score is a measure of the amount of surface protection on the stream bank provided by vegetation, root mass, debris, or armoring at the resource location, reflecting the vulnerability of the stream bank surface to fluvial erosion. The surface cover score is represented as the whole number value of the percentage of soil surface covered on the bank. A stream bank with half of its surface area covered by vegetation would receive a surface cover score of 50.

6.6.3 Planform Score

The planform score is based on the resource location relative to the stream meander pattern. On sinuous streams, the rate of erosion is generally greater on the outside of bends due to the momentum of water and flow patterns within the channel. Therefore a higher planform score

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is assigned to resources located on the outside of channel bends to account for the relative potential for erosion problem progression over time. Conversely, lower planform scores are assigned to those located in straight segments and on the inside of bends, respectively, as shown in Table 6.6-2. Figure 6.6-2 depicts how resources are differentially threatened with respect to their relative location to stream planform patterns.

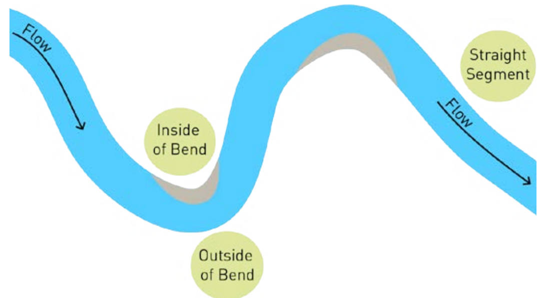

Figure 6.6-2 Resource Location Relative to Stream Pattern

Table 6.6-2 Planform Score

Resource Location	Planform Score
Outside of Bend	100
Straight Reach	25
Inside of Bend	0

6.7 Results

Using the methods described above, erosion problem scores are calculated for individual sites and for the geomorphic like reaches identified in the stream assessments. The resulting scores are used to quantify the relative priority of erosion concerns along the drainage systems throughout the City of Austin. Figure 6.7-1 shows all erosion reaches with erosion studies by level of concern (e.g., Very High, High, etc.). Unsurprisingly, the majority of the reaches with the highest (worst) problem severity scores are those in the urban core, where the majority of development occurred prior to the advent of Austin's protective watershed regulations.

Table 6.7-1 shows the scores for the watersheds in which Erosion Assessments or targeted investigations have been performed. Capital projects and other solutions are not selected based on this information (they use the more specific reach information, see Section 10), but it gives an idea of where the problems of greatest concern are located. A relatively high percentage of the total erosion reach score total is in Urban watersheds such as Shoal, Waller, and Boggy, plus long-developed Williamson Creek. Little Walnut has the highest count of total erosion sites (139), the majority of which are Type 3 sites, which represent potential future threats to resources such as roads, structures, fences, and utilities (see Table 6.7-2 for the definition of Type 1, 2, and 3 sites). Shoal has the second highest count of total erosion sites (125), the majority of which are also Type 3 sites. Neither Shoal nor Little Walnut have any Type 1 sites, which represent an imminent threat to a habitable structure or roadway.

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Waller Creek is the only watershed studied with more than one Type 1 site. Other watersheds with Type 1 sites include Boggy Creek, the Colorado River, and Gilleland Creek. Because of the severity of Type 1 sites, as well as other stability factors (see Section 6.4 above for a description of the erosion scoring methodology), there is not a one-to-one correlation between total erosion sites and the final erosion problem score. The presence of erosion sites, however, serves as an indicator of degrading stream stability. Furthermore, the presence of Type 3 erosion sites provide significant insight into potential future stream conditions if corrective actions are not taken. See Section 10 for a discussion of proposed erosion capital solutions.

Figure 6.7-2 shows the scoring distribution for all erosion reaches in which erosion assessments or targeted investigations have been performed. Figure 6.7-3 zooms in on the Top 20 of these scores. It is notable that the top score (100 points: lower Waller Creek) is much higher than the next highest scores. After approximately 50 reaches, the scoring pattern flattens out with relatively low scores.

Table 6.7-2 presents the Top 20 ranked reaches by erosion problem score. At this time, all problem areas are considered for potential solutions. Again, unsurprisingly, the reaches with the highest (worst) problem severity scores are in or near the urban core, where the majority of development occurred prior to the advent of Austin's protective watershed regulations.

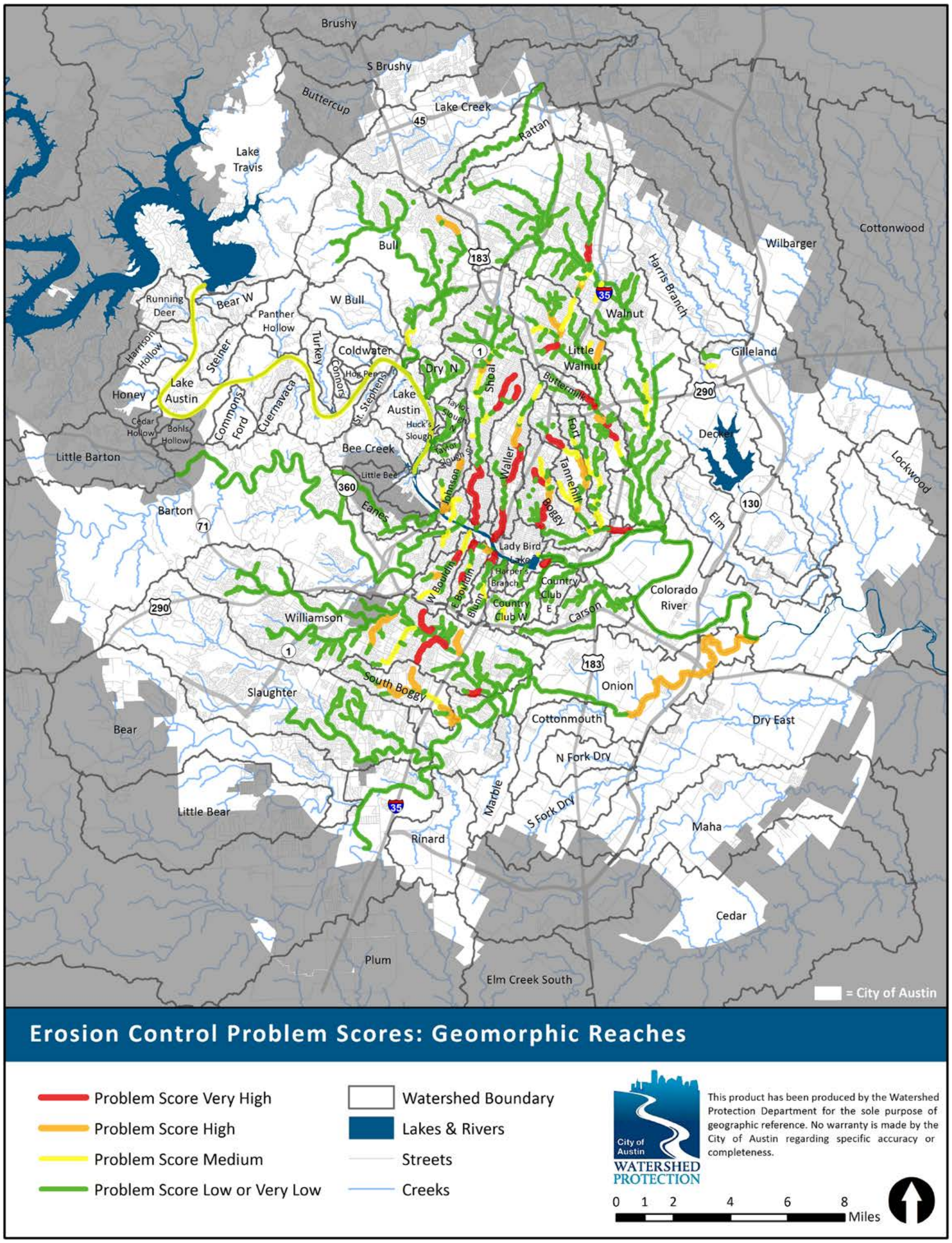

Figure 6.7-1 Map of Erosion Problem Scores by Geomorphic Reach (October 2015)

Table 6.7-1 Problem Score Summary by Watershed: Erosion Sites & Geomorphic Reaches (October 2015)

Watershed	Phase	Erosion Sites*					Reach Count	Geomorphic Reaches	
		Count by Type			Total Count	Pct. Total Count		Total Score	Pct. Total Score
		1	2	3					
Barton	1	0	1	16	17	1.5%	13	12	0.8%
Blunn	1	0	4	11	15	1.3%	6	45	3.0%
Boggy	1	1	7	53	61	5.4%	23	124	8.1%
Bull	1	0	1	33	34	3.0%	34	34	2.2%
Buttermilk	1	0	0	17	17	1.5%	6	36	2.4%
Carson	2	0	0	14	14	1.2%	34	22	1.4%
Country Club East	1	0	0	5	5	0.4%	6	5	0.3%
Country Club West	1	0	3	18	21	1.9%	16	40	2.6%
Colorado River	2	1	1	1	3	0.3%	2	0	0.0%
Decker	2	0	1	5	6	0.5%	0	0	0.0%
Dry Creek North	2	0	0	6	6	0.5%	4	2	0.1%
Eanes	2	0	0	2	2	0.2%	2	0	0.0%
East Bouldin	1	0	13	35	48	4.2%	18	86	5.6%
Elm	2	0	0	1	1	0.1%	0	0	0.0%
Fort Branch	1	0	3	34	37	3.3%	19	33	2.1%
Gilleland	2	1	9	32	42	3.7%	2	5	0.4%
Harpers Branch	1	0	2	7	9	0.8%	8	5	0.3%
Harris Branch	2	0	0	5	5	0.4%	0	0	0.0%
Johnson	1	0	2	18	20	1.8%	10	32	2.1%
Lady Bird Lake	2	0	2	12	14	1.2%	7	26	1.7%
Lake Austin	2	0	1	2	3	0.3%	1	5	0.4%
Little Walnut	1	0	16	123	139	12.3%	45	170	11.1%
Onion	2	0	16	15	31	2.7%	13	25	1.6%
Rattan	2	0	0	3	3	0.3%	2	0	0.0%
South Boggy	2	0	8	30	38	3.4%	11	45	2.9%
Shoal	1	0	5	120	125	11.0%	41	217	14.2%
Slaughter	2	0	4	43	47	4.1%	7	0	0.0%
Tannehill Branch	1	0	2	36	38	3.4%	14	70	4.6%
Taylor Slough North	2	0	0	1	1	0.1%	2	1	0.1%
Taylor Slough South	2	0	0	3	3	0.3%	2	3	0.2%
West Bouldin	1	0	4	39	43	3.8%	12	61	4.0%
Walnut	1	0	26	68	94	8.3%	66	118	7.7%
Waller	1	2	15	56	73	6.4%	14	168	11.0%
Williamson	1	0	7	112	119	10.5%	57	137	9.0%
Totals:		**5**	**153**	**976**	**1,134**	**100.0%**	**497**	**1,530**	**100.0%**
Maximum Value:		2	26	123	139	12.3%	66	217	14.2%

**Includes only Erosion Sites with "Active" status*

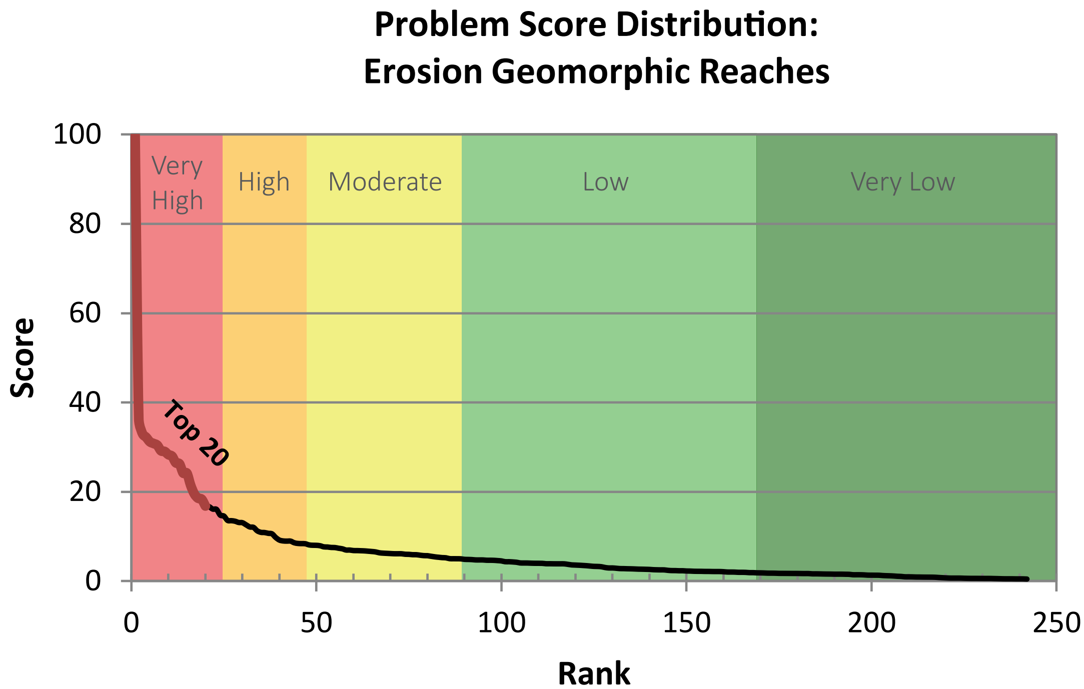

Figure 6.7-2 Problem Score Distribution: All Non-Zero Scores (October 2015)

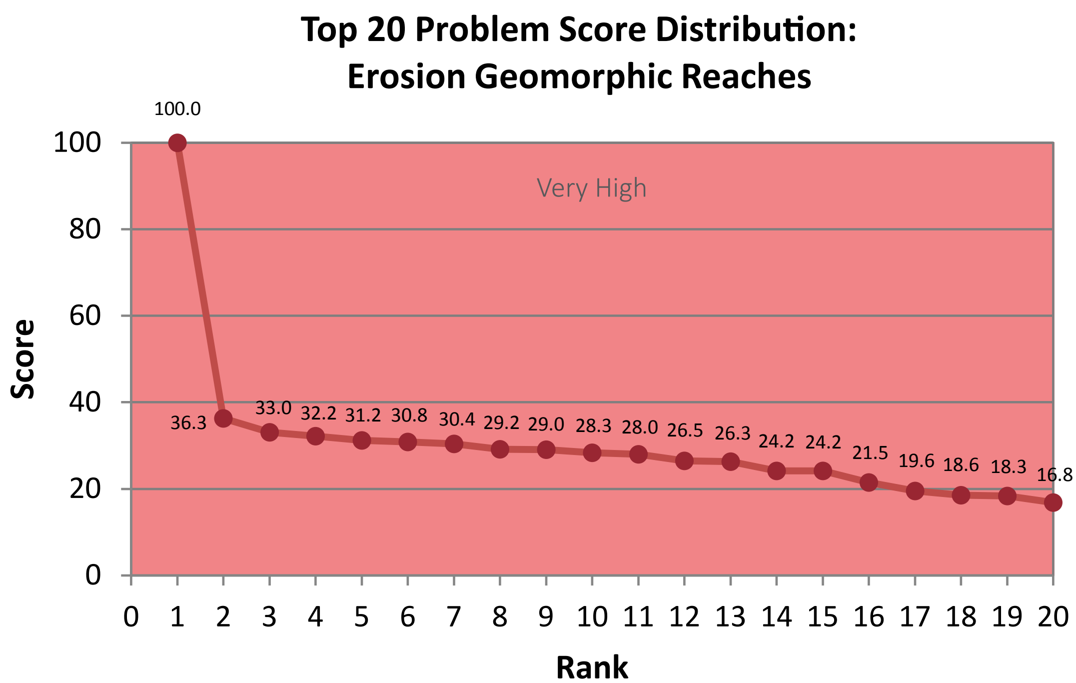

Figure 6.7-3 Problem Score Distribution: Top 20 Ranked Scores (October 2015)

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Table 6.7-2 Top 20 Ranked Problem Scores: Erosion Geomorphic Reaches (October 2015)

Rank	Problem Area (Reach ID)	Watershed	Location	Score
1	WLR-1	Waller	Along Waller Creek from Confluence north to E 5th St	100.0
2	SHL-4	Shoal	Pease Park along Shoal Creek from MLK Blvd north to W 25th St	36.29
3	LWA-JMA-1	Little Walnut	Along Little Walnut Creek from Thurmund St north to Payton Gin Rd	33.04
4	SHL-3	Shoal	Pease Park along Shoal Creek from W 4th St to MLK Blvd	32.21
5	WLN-WEL-2	Walnut	Along Wells Branch Creek tributary from W Parmer Ln to Walnut Creek Park Rdt	31.20
6	BLU-1	Blunn	Along Blunn Creek from Little Stacy Park north to Confluence	30.82
7	SHL-HAN-GVR-2	Shoal	Along the Hancock Branch of Shoal Creek from Romeria Dr north to Ruth Ave and Grover Ave	30.43
8	BOG-1	Boggy	Along Boggy Creek from US Hwy 183 to the confluence with the Colorado River	29.19
9	WBO-2	West Bouldin	Along West Bouldin Creek from Jewell St south to W Johanna St	29.04
10	LWA-3	Little Walnut	Little Walnut Creek from Dottie Jordan Park at Loyola Ln to Manor Rd	28.33
11	BMK-1	Buttermilk	Along Buttermilk Creek from US 290 northeast to near E Anderson Ln between Cameron Rd and Blessing Ave	27.97
12	BOG-5	Boggy	Rosewood Park along Boggy Creek from E 9th St north to near E 16th St	26.51
13	WMS-BCR-1	Williamson	Along the Bitter Creek tributary of Williamson Creek from Branchwood Dr to Williamson Creek East Greenbelt	26.26
14	SHL-5	Shoal	Pease Park along Shoal Creek from W 25th St north to W 29th St	24.20
15	WLR-4	Waller	Eastwoods Park along Waller Creek from Dean Keeton St north to E 45th St	24.18
16	WMS-RIC-1	Williamson	Along Richmond tributary of Williamson Creek from Redd St to Williamson Creek near S 1st St	21.51
17	EBO-4C	East Bouldin	Along East Bouldin Creek from W Oltorf St through Gillis Park to Cumberland Rd	19.55
18	SHL-HAN-3	Shoal	Along the Hancock Branch of Shoal Creek along Arroyo Seco from W North Loop Blvd north to W St Johns Ave	18.58
19	TAN-7	Tannehill Branch	Along Tannehill Branch from west of Berkman Dr. to Cameron Rd	18.34
20	EBO-1D	East Bouldin	Along East Bouldin Creek from south of Barton Springs Rd south to Columbus St	16.83

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Section 7

7 Water Quality Assessment

7.1 Background

Exemplary surface and groundwater quality has always and continues to be central to Austin's identity and well-being. Clear, flowing water is vital to human and ecological health, property values, and tourism. Since at least the early 1970s, Austin recognized that uncontrolled urbanization threatens water quality and, with it, these invaluable community resources: our lakes, rivers, creeks, and springs. Sources of water quality problems are multitudinous and complex to study and control. Key concerns include increases in runoff, sediment, nutrients, metals, litter, bacteria, and degradation of aquatic and riparian habitat.

To assess this complexity, WPD developed its Environmental Integrity Index (EII) monitoring and scoring system to compare a range of conditions across Austin's watersheds. These systems were developed by WPD staff with guidance from two EPA documents: *Urban Targeting and BMP Selection: An Information and Guidance Manual for State NPS Program Staff Engineers and Managers* (US EPA, 1990) and *Geographic Targeting: Selected State Examples* (US EPA Office of Water, EPA-841-B-93-001, February, 1993). Like the scoring systems for flood and erosion control, scores range between 0 and 100, but with EII higher scores indicate better water quality. The water quality problem scoring system has been revised to identify ten separate problems with currently feasible solution options (COA, 2008). Individual problem scores are generated from combinations of Environmental Integrity Index (EII) subcomponents (COA, 2002). Current and future Altered Hydrology scores are further generated from Soil and Water Assessment Tool (SWAT) modeling (Neitsch et al., 2009) in development by WPD staff. An additional CIP water quality problem score is also generated for use in mission integration activities for water quality structural CIP project solutions. This score is comprised of problem components that are considered “fixable” by CIP structural solutions. These include: poor riparian vegetation, unstable channels, fertilizer runoff, and toxins in sediment. Section 7.4.12 discusses Water Quality CIP Problem Scores in greater detail. Problem scores range from 0 - 100, with 100 being the worst problem.

WPD staff collect additional environmental quality data not directly related to project prioritization for the Master Plan. Stormwater volume and pollutant event mean concentration data are collected during stormwater runoff events for sites in small areas with relatively homogeneous land use by WPD staff. Stormwater sampling is also used to evaluate pollutant removal performance of different water quality structural controls. Stormwater runoff samples and flow are measured in large watersheds by the U.S. Geological Survey under contract to WPD to track large scale temporal changes in the

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quality of stormwater runoff. Extensive lake monitoring, including assessment of aquatic macrophytes, phytoplankton, water quality, sediment quality, benthic macroinvertebrates, trash, and habitat collected by multiple city departments and state agencies, is conducted for the WPD multi-metric Lakes Index.

Groundwater quality data are collected routinely by WPD staff at multiple outlets of the Barton Springs Complex, the primary discharge point of the Barton Springs Segment of the Edwards Aquifer, to track long term temporal trends in aquifer water quality. Additional well water quality sampling is done by the U.S. Geological Survey under contract to WPD from multiple wells in both the Northern and Barton Springs segments of the Edwards Aquifer. Regular population surveys of the federally threatened Jollyville Plateau salamander (*Eurycea tonkawae*) and federally endangered Austin blind (*Eurycea waterlooensis*) and Barton Springs (*Eurycea sosorum*) salamanders are conducted by WPD to evaluate distribution, life history, and status over time of these sensitive species. Riparian functional assessments are conducted on a regular basis to evaluate the success of riparian restoration methods and identify opportunities for improving the efficiency of restoration techniques.

7.2 Overview of Assessment Methodology

Section 7 describes the methods used to investigate problems associated with water quality degradation. The methodology takes water quality data collected from field sampling, ranks problems by severity, and proposes a list of Top 20 problem areas. Solutions to these problems are discussed later in Section 10.

Figure 7.2-1 graphically presents the methodology for water quality.

1. **Collect Field Data.** Watersheds are divided into subwatersheds for detailed, biennial sampling using Austin's Environmental Integrity Index (EII) scoring system. EII scores for each EII (stream) reach are catalogued as an overall indicator of watershed ecological integrity.
2. **Generate Problem Scores.** CIP Problem Scores, consisting of EII subcomponents feasibly addressed by stormwater treatment capital projects, are compiled and normalized on a 100-point scale for each EII reach. The higher the score, the more severe the problem. Normalized scores are assigned a narrative rating of Very High to Very Low. The 20 highest scoring (ranking) reaches are identified.
3. **Prioritize Problems for CIP Solution Integration.** High ranking problem EII reaches are further evaluated for site-specific feasibility considerations. Section 10 discusses how projects are developed and prioritized from priority problem areas.

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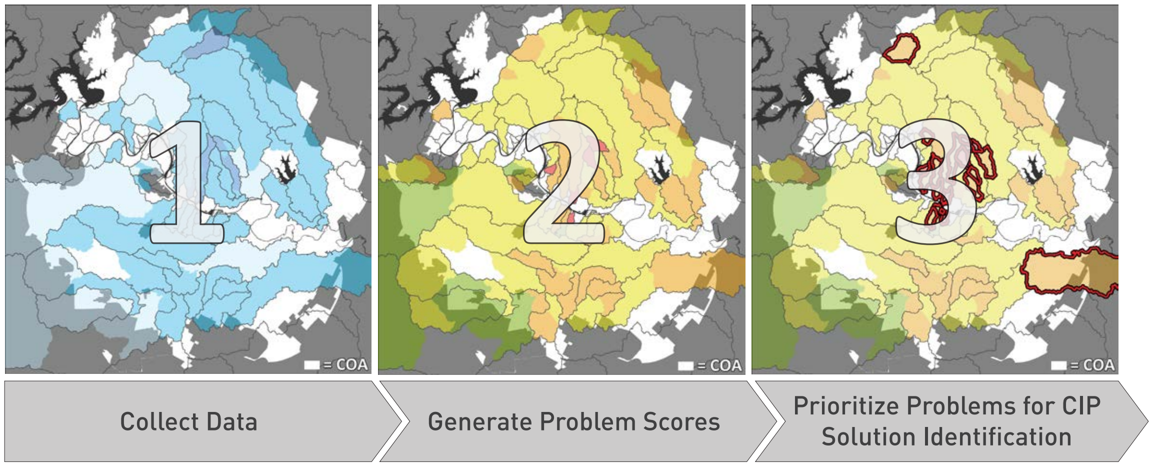

Figure 7.2-1 Water Quality Prioritization Methodology (2015). Steps 1 & 2 are described here in Section 7, while Step 3 is described in Section 10.

7.3 Study Methods

To consider water quality problems at both local and larger scales, major creeks within each watershed are subdivided into segments known as Environmental Integrity Index (EII) reaches. This approach is similar to that used for the Erosion Control mission, where creeks are divided into erosion reaches. A total of 118 reaches in 49 watersheds are currently sampled across Austin for the EII.[1] The original 2001 Master Plan studied a total of 70 EII reaches in the 17 Phase 1 watersheds.

The EII is a multi-metric index that integrates information about the physical integrity, chemical, and biological conditions of a sampling location into a single score that reflects the overall ecological function of the site. High EII scores represent more fully functional creek reaches that are less degraded by human disturbance. Water quality problem scores, derived from these EII scores, are discussed more thoroughly in Section 7.4 of this chapter, and are a combination of a specific subset of the components of the EII to identify degraded sampling locations. Water quality problem scores use transformed EII components such that high values represent sampling locations with limited ecological functionality. High water quality problem scores identify sites with environmental problems that may be remediated with water quality structural controls.

Each EII reach is delineated based on relatively homogeneous land use patterns, hydrology, geomorphology, hydrology, and point source impacts in the intervening contributing drainage areas. Each reach is represented by a single sample location and, beginning in 2009, sampled every other year. During the sample year, four water quality events (a field visit to the sampling location to

[1] In the past, eight additional, individual reaches were also monitored but are no longer sampled due to: dry conditions (Bear, Reach 2; Eanes, Reach 1; Huck's Slough, watershed; Onion, Reach 4a; Rinard, Reach 3; and Slaughter, Reach 2), lack of habitat (Little Bee, Reach 1), or statistical insignificance (Dry Creek North, Reach 2). Dry conditions or lack of habitat prevent full and representative data collection.

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collect data) and one sediment, physical integrity, and biological event are taken. Sampling occurs on an annual basis; however, watersheds are staggered such that each watershed is sampled every other year.

Some creek reaches which consistently do not maintain baseflow are not sampled for the Environmental Integrity Index. These creek reaches are primarily over the recharge zone of the Edwards Aquifer, and under normal conditions flow only for short time periods after rainfall. This natural absence of creek flow in normal conditions would artificially lower the scores for these creek reaches if they were included in the EII. Upstream EII reaches, in combination with groundwater monitoring data separate from the EII, are used by WPD staff to assess the water quality of aquifer recharge.

The Austin Lakes Index (ALI) is similar to the Environmental Integrity Index (EII) in that it combines data from multiple datasets to yield a single, holistic description of the overall ecological integrity of the water body. Like the EII, the ALI includes water chemistry, sediment, habitat, and aquatic life data. Because reservoirs function differently than Austin streams, the ALI separately incorporates data on the trophic status of the lakes based on floating algae data as well as data on the amount of both native and nuisance rooted aquatic plants. Three lakes are currently studied for the ALI.

Figure 7.3-1 depicts the EII subwatersheds and ALI study lakes.

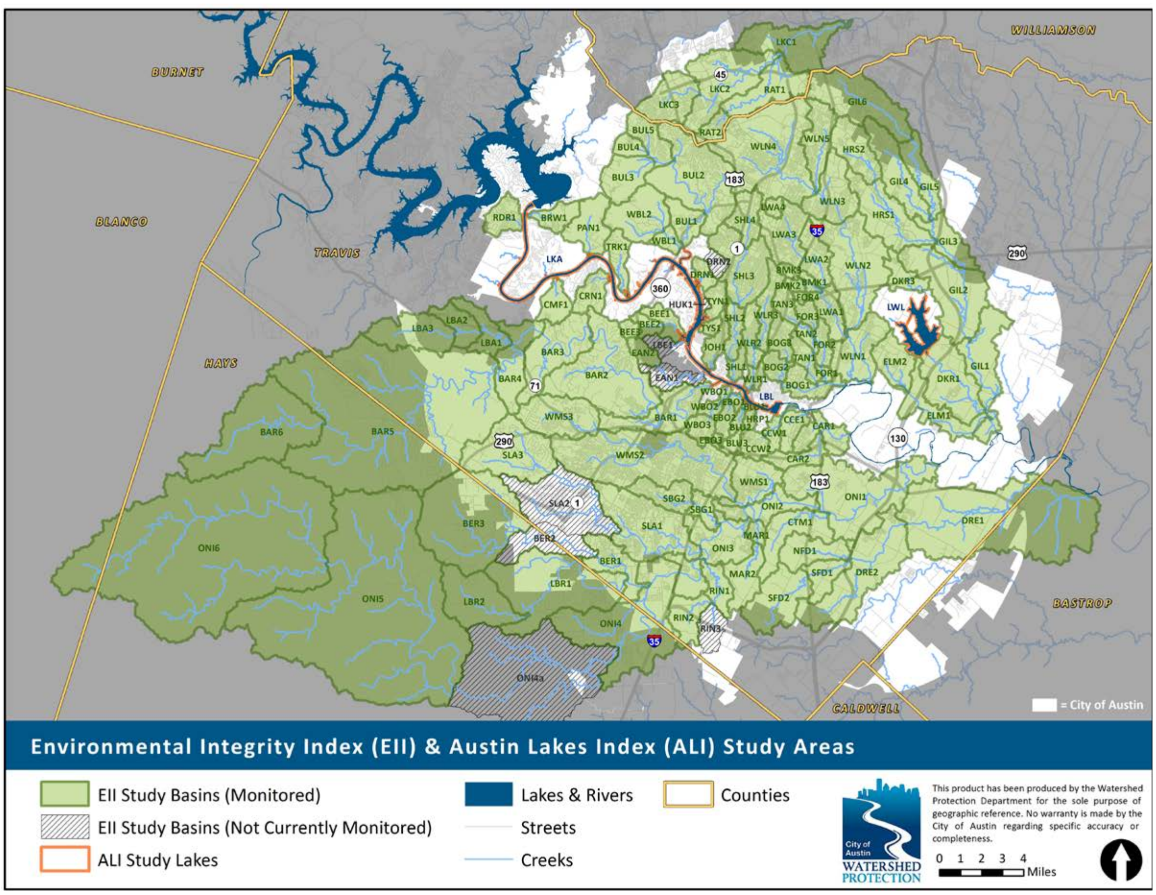

Figure 7.3-1 Environmental Integrity Index (EII) & Austin Lakes Index (ALI) Study Basins (2015)

The EII methodology is a tool developed by the City of Austin to monitor and assess the ecological integrity and the degree of impairment of Austin creeks (*Environmental Integrity Index Water Quality Technical Assessment Methodology*, City of Austin, Watershed Protection Department, August 1997; see also COA, 2002). A primary motivation for developing the EII was to address the concern that water chemistry data alone does not adequately describe the health of water resources. Measuring a range of chemical, physical, and biological conditions results in a more accurate assessment of stream health.

To formulate the EII, the designated water uses specified in the Clean Water Act Section 303 [c](2)(A) that are applicable to Austin area creeks were identified and condensed into six protection categories, referred to as "subindexes" of the overall EII score:

1. Contact Recreation
2. Non-Contact Recreation and Aesthetics
3. Water Quality
4. Sediment Quality
5. Physical Integrity
6. Aquatic Life Support

Table 7.3-1 lists the specific parameters under each of these categories. These were selected after careful review of other state and federal water quality monitoring and assessment protocols in combination with local best professional judgment. In particular, the US Environmental Protection Agency (USEPA) *Rapid Bioassessment Protocols* (Plafkin et al., 1989) and the Texas Natural Resource Conservation Commission (TNRCC) *Use Attainability Assessment and Physical Characteristic Assessment* (TNRCC, 1988) were useful references. However, some of the EII procedures are new or modified from existing state or federal protocols to better reflect Central Texas ecoregions and local conditions.

Numeric EII scores from 0 (lowest/worst) to 100 (highest/best) are assigned to each subindex based upon the sampling data. Detailed sampling procedures and EII score calculation methods are documented in ERM quality assurance project plans and current methods and EII results are available via the Internet. The overall EII score is calculated as the average (mean) of these six subindices, which equally weights each subindex. Sediment quality is sampled at only one site per watershed (the most downstream site) and the resulting score is assigned to all upstream reaches.

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Table 7.3-1 Summary of EII Categorical Components used in EII Score Calculation

Contact Recreation Swimming/ Wading	Non-Contact Recreation/ Aesthetics	Water Quality	Sediment Quality	Physical Integrity	Aquatic Life Support
• E. coli	• Surface Appearance • Litter • Odor • Clarity • Flow Volume • Percent Algae Cover	• E. coli • Total Suspended Solids • Conductivity • Nitrate-Nitrogen • Orthophosphorus • Ammonia-Nitrogen	• Metals • PAHs • Organo-chlorides • Pesticides • PCBs	• Epifaunal Substrate • Velocity/Depth Regime • Channel Alteration • Sediment Deposition • Embeddedness • Channel Flow Status • Bank Stability • Frequency of Riffles • Bank Vegetation • Riparian Width	• Macroinvertebrate Community Structure • Diatom Community Structure

For EII reaches, each EII score was categorized with a narrative rating based upon the ranges shown in Table 7.3-2.

Table 7.3-2 EII Narrative Rating Score Ranges

Current Narrative Score	Current Numeric EII Score	Target Narrative Score
Very Bad	0 - 12	Good
Bad	13 - 35	Good
Poor	26 - 38	Good
Marginal	39 - 50	Good
Fair	51 - 63	Good
Good	64 - 75	Very Good
Very Good	76 - 88	Excellent
Excellent	89 - 100	Excellent

EII results are calculated annually, and are available in detailed reports including spatial and temporal analyses via the City of Austin website.[2] Table 7.3-3 and Figure 7.3-2 present EII scores averaged across entire watersheds (i.e., multiple reaches within each watershed are combined into an average score for comparison purposes).

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[2] http://austintexas.gov/department/environmental-integrity-index

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Table 7.3-3 Problem Scores by Watershed: Water Quality EII Reach Scores and CIP Problem Scores (Oct. 2015)

Watershed	Phase	Reach Count	EII/ALI Reach Score			CIP Problem WQ Score		
			Avg. Numeric Score	Avg. Narrative Score	Wshed Rank	Avg. Numeric Score	Avg. Numeric Score	Wshed Rank
Barton	1	6	79	Very Good	7	0	Low	50
Bear	2	3	81	Very Good	5	39	Moderate	34
Bear West	2	1	83	Very Good	1	11	Low	48
Bee	2	3	76	Very Good	11	32	Moderate	38
Blunn	1	3	63	Fair	28	50	Moderate	26
Boggy	1	3	59	Fair	34	58	High	18
Buttermilk Branch	1	3	49	Marginal	49	95	Very High	2
Bull	1	5	77	Very Good	9	57	High	20
Carson	2	2	65	Good	24	36	Moderate	35
Commons Ford	2	1	82	Very Good	2	58	High	19
Cottonmouth	2	1	61	Fair	30	94	Very High	3
Country Club East	1	1	54	Fair	44	29	Moderate	41
Country Club West	1	2	64	Good	27	46	Moderate	29
Cuernavaca	2	1	75	Good	12	43	Moderate	31
Decker	2	2	66	Good	23	26	Moderate	43
Dry East	2	2	59	Fair	34	63	High	15
Dry North	2	2	72	Good	18	65	High	14
Eanes	2	2	43	Marginal	52	62	High	16
East Bouldin	1	3	58	Fair	39	77	Very High	8
Elm	2	2	57	Fair	40	15	Low	47
Fort Branch	1	4	51	Fair	47	34	Moderate	36
Gilleland	2	6	65	Good	25	48	Moderate	28
Harpers Branch	1	1	45	Marginal	51	99	Very High	1
Harris Branch	2	2	59	Fair	34	49	Moderate	27
Huck's Slough	2	1	Not sampled recently due to dry conditions			Not sampled recently due to dry conditions		
Johnson	1	1	52	Fair	46	80	Very High	6
Lady Bird Lake*	2	1	57	Fair	40	Not calculated		
Lake	2	3	74	Good	16	50	Moderate	24
Lake Austin*	2	1	51	Fair	48	Not calculated		
Little Barton	2	3	82	Very Good	4	32	Moderate	39
Little Bear	2	2	82	Very Good	2	9	Low	49
Little Bee	2	1	Not sampled recently due to lack of habitat			29	Moderate	41
Little Walnut	1	4	70	Good	22	60	High	17
Marble	2	2	65	Good	25	71	High	10
North Fork Dry	2	1	57	Fair	40	86	Very High	5
Onion	2	7	80	Very Good	6	19	Low	45

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Table 7.3-3 continued

Watershed	Phase	Reach Count	EII/ALI Reach Score			CIP Problem WQ Score		
			Avg. Numeric Score	Avg. Narrative Score	Wshed Rank	Avg. Numeric Score	Avg. Numeric Score	Wshed Rank
Panther Hollow	2	1	72	Good	18	50	Moderate	24
Rattan	2	2	59	Fair	38	17	Low	46
Rinard	2	3	74	Good	14	55	High	21
Running Deer	2	1	72	Good	18	68	High	13
South Boggy	2	2	60	Fair	33	55	High	22
South Fork Dry	2	2	63	Fair	29	70	High	11
Shoal	1	4	59	Fair	34	70	High	11
Slaughter	2	3	77	Very Good	10	39	Moderate	33
Tannehill Branch	1	3	60	Fair	31	74	High	9
Taylor Slough North	2	1	74	Good	14	55	High	22
Taylor Sough South	2	1	57	Fair	40	79	Very High	7
Turkey	2	1	78	Very Good	8	31	Moderate	40
Waller	1	3	46	Marginal	50	92	Very High	4
Walnut	1	5	74	Good	13	32	Moderate	37
Walter E. Long Lake*	2	1	54	Fair	44	Not calculated		
West Bouldin	1	3	60	Fair	32	46	Moderate	29
West Bull	2	2	74	Good	17	23	Low	44
Williamson	1	3	70	Good	21	39	Moderate	32
Totals:		**129 †**	**Avg = 67**			**Avg = 48**		
Maximum Value:		7	83	Very Good		99	Very High	

* *Data collected using the Austin Lakes Index (ALI) methodology*

† *Total includes includes 118 reaches currently sampled using the EII, 3 reaches sampled using the ALI, 6 reaches (BER1, EAN1, HUK1, ONI4a, RIN3, SLA2) not currently sampled due to dry conditions, 1 reach (DRN2) no longer sampled due to statistical insignificance, and 1 reach (LBE2) not currently sampled due to lack of habitat.*

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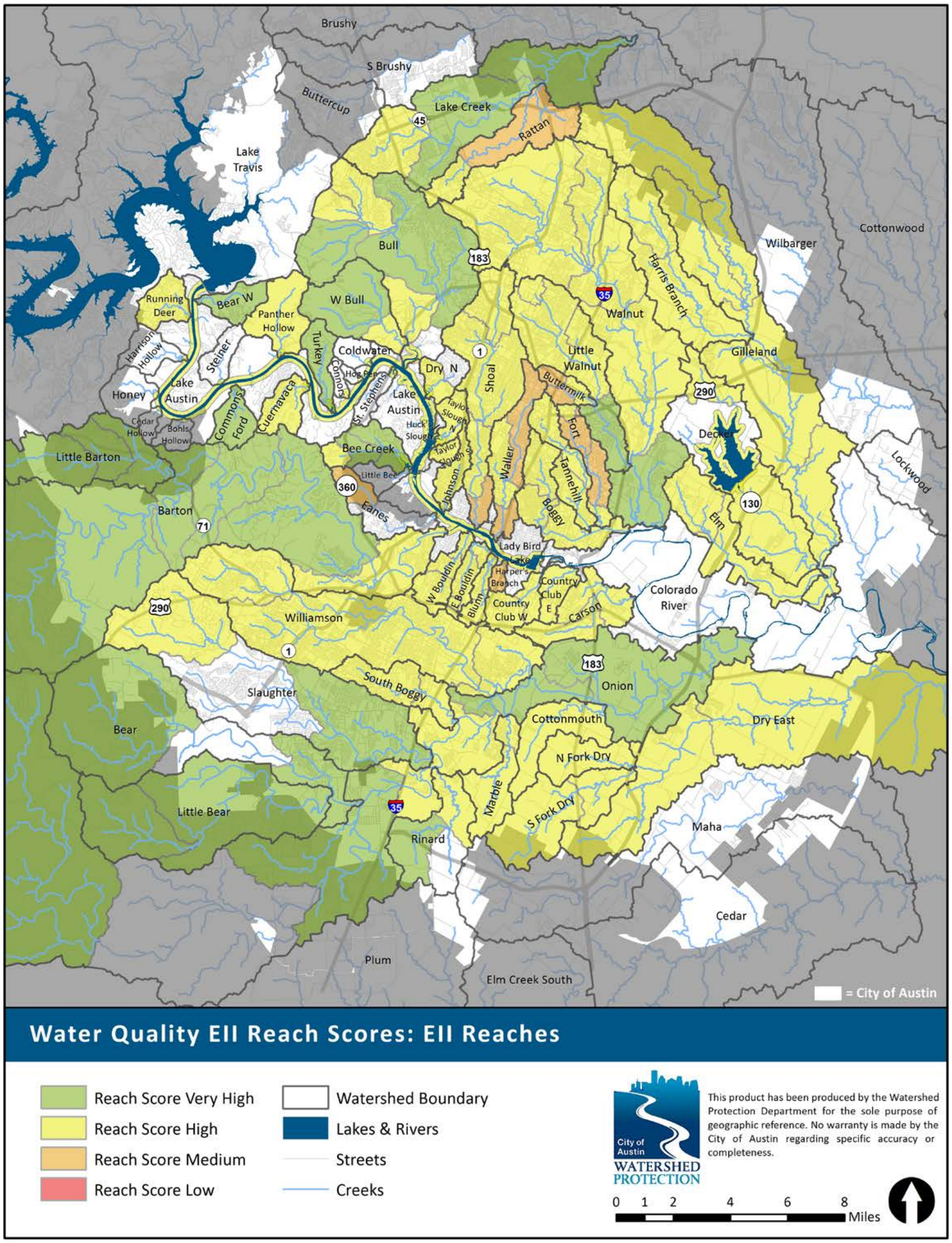

Figure 7.3-2 Map of EII Reach Scores by Sampling Reach (2015)

7.4 Problem Score

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While the EII remains the overall indicator of watershed ecological integrity, ten individual problem scores derived from EII subcomponents are used for prioritization purposes for the set of existing, feasible solution options to address water quality concerns in Austin (City of Austin, 2009).

Table 7.4-1 presents the nine specific current problems assessed through existing EII components and one future problem score to be assessed using SWAT modeled hydrology. The calculation method for each component is detailed below. Problem scores have an inverse scale to EII subindex and component scores, such that EII component scores range from 0 (worst condition) to 100 (best condition), while problem scores range from 0 (least severe problem) to 100 (most severe problem). When a problem score calculation involves only one set of EII component scores, it is necessary to invert the scale of the EII component by subtracting from 100. For some problem scores, the calculation involves the difference of two sets of EII component scores. In these cases, the magnitude of the difference between these sets of EII component scores functionally reflects the scale of the problem. For example, if nutrients are high but fecal bacteria are low, the nutrients are most likely from fertilizer and not from wastewater. In these cases, it is not necessary to subtract from 100.

Table 7.4-1 Water Quality Problem Scores and Solutions

Problem to Fix	Solution Type Examples
Toxins in sediment	Capital Improvement Projects (CIP), regulations (e.g. pavement sealant ban)
Litter	Programs (e.g., Keep Austin Beautiful, creek cleanups)
Bacteria from animals	Programs (e.g., Scoop the Poop)
Sewage	CIP (e.g., Austin Clean Water Program)
Nutrients (non-sewage)	CIP, programs (e.g., Grow Green)
Construction runoff	Regulations, programs (e.g., Environmental Inspection)
Poor riparian vegetation	CIP (e.g., riparian restoration projects)
Unstable channels	CIP (e.g., stream channel restoration projects)
Altered hydrology: Current	CIP (e.g., stormwater pond retrofits), programs, regulations
Altered hydrology: Future	Regulations

Problem scores may be less than zero for some problems because the subtraction of two unrelated EII components. Negatively scored problems are considered low priority and set to zero in any score combination method. Problems are scaled 0-100 for any combinatory method to equally weight component problems.

Note that EII scores, not problem scores, continue to be the overall measure of environmental integrity for a given sampling reach or watershed. EII scores are expressly balanced and weighted to provide a snapshot of overall creek health of the parameters measured. Problem scores are

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indicators and are used to direct solution implementation. For more detailed discussion, please see Appendix C which presents the Watershed Profiles for water quality solution identification. Table 7.3-3 presents averaged Water Quality CIP Problem Scores (i.e., multiple reaches within each watershed are combined into an average score for comparison purposes).

7.4.1 Toxins in Sediment

Sediment data are collected from the mouth of each EII-monitored watershed and analyzed for PAHs, pesticides, and metals. Sediment EII scores are intended to be representative of the toxic load for the entire watershed. The worst (lowest) EII component (PAH, pesticide, or metal) is used in the calculation as follows, which inverts the worst (lowest) component of the sediment subindex by subtracting that value from 100:

Problem Score = 100 – min (PAH, pesticide, or metal EII)

7.4.2 Litter

Litter EII component scores collected for the aesthetics subindex are subtracted from 100 to identify reaches with litter problems. EII litter scores are based on a visual assessment litter quantity and type at the representative monitoring site for each reach. The formula is as follows, which converts the litter component score by subtracting from 100:

Problem Score = 100 – (Litter EII)

7.4.3 Bacteria from Animals

The bacteria from animals problem score was developed to identify reaches with low concentrations of nutrients (ammonia, nitrate, and orthophosphorus) and algae (as characterized by the percent algae coverage component of the aesthetics subindex), but high fecal bacteria indicative of fecal contamination from animal sources and not leaking wastewater infrastructure. Areas with high fecal bacteria concentrations that are influenced by runoff from high-traffic dog parks would exemplify high-priority problem reaches. The dual use of the worst (lowest) nutrient or algae EII component allows for the identification of reaches that may have low in-stream nutrient concentrations because of high algal biomass accrual and are thus nutrient enriched systems. Subtraction from 100 is not necessary for this problem score as it involves the difference between two sets of component scores. The formula is as follows, which subtracts the bacteria component score from the worst of either the nutrient or percent algae cover component score:

Problem Score = min (nutrient or % algae EII) – (bacteria EII)

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7.4.4 Sewage

The sewage problem score was designed to identify reaches with both high nutrients (ammonia, nitrate, or orthophosphorus) and fecal bacteria typical of areas affected by leaking or defective wastewater infrastructure. Again, the worst (lowest) nutrient or algae component EII score is used to more accurately represent the level of nutrient enrichment present. The formula is as follows, which inverts the average of the bacteria component score with the worst (lowest) nutrient or percent algae cover component score:

Problem Score = 100 – average [bacteria EII and min (nutrient or % algae EII)]

7.4.5 Nutrients (Non-Sewage)

The nutrients problem score is the inverse of its bacteria-from-animals counterpart. It is designed to identify reaches with low bacteria and high nutrients or algae cover indicative of reaches affected by nutrient enrichment from excessive or improper lawn fertilizer usage or other sources. This problem will be inverse from the bacteria from animals problem score. Note that EII scores are 0-100 (bad to good) such that the subtraction of a good bacteria EII component score (a high value) from a bad nutrient or algae EII component score (a low value) would yield a large nutrients problem score. Subtraction from 100 is not necessary for this problem as it is the difference between two sets of component scores. The formula is as follows:

Problem Score = (bacteria EII) – min (nutrient or % algae EII)

7.4.6 Construction Runoff

The sediment from construction runoff problem score was designed to identify reaches with stable channels but high in-stream total suspended solids (TSS from the EII water quality subindex) and high substrate embeddedness (from the sediment deposition component of the EII habitat quality subindex). The worst of left or right bank stability scores are used in the calculation (Note: one bank might be in poor and the other in good condition; the key is to identify areas in poor condition, hence the use of the worst of the two scores for each EII reach). Bank stability is included in the calculation to exclude highly depositional reaches where the source of stream sediments is likely bank sediments from erosion of unstable areas. Subtraction from 100 is not necessary for this problem as it is the difference between two sets of component scores. The formula is as follows, which subtracts the stability of the bank from the average of the suspended sediment and sediment deposition component scores:

Problem Score = (bank stability EII) – average (TSS, sediment deposition EII)

7.4.7 Poor Riparian Vegetation

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The poor riparian vegetation problem score was designed to prioritize reaches with both low quality (low diversity) and low quantity (narrow) riparian zones. As with Construction Runoff, the calculation is done separately for the right and left banks and the worst value is used to represent the reach. Division of the bank vegetative protection score by 100 effectively converts it to a weighting factor to modify the riparian zone width component. Riparian zone assessments are completed as part of the habitat quality (also known as "physical integrity") EII subindex. An optimal EII reach would have wide and diverse riparian zones on both sides of the creek. The scoring formula is as follows, which inverts the scale of the product of the quality times the quantity of the riparian area by subtracting that product from 100:

Problem Score = 100 – [(vegetative protection EII/100)*(riparian width EII)]

7.4.8 Unstable Channels

The unstable channel problem score was designed to identify creek reaches destabilized by urbanization or other unnatural causes (A level of dynamism is expected in natural channels, but does not receive a poor score in this system.). The differential weighting of bank stability and channel alteration ranks altered, unstable reaches with the highest problem priority followed by unaltered, unstable reaches. The unstable channel and construction runoff problems are effectively mutually exclusive. Bank stability and channel alteration measurements are collected during the habitat EII subindex field work. This problem inverts the scale of the bank stability and channel alteration components by subtracting from 100, but differentially weights the bank stability to be three times more important than channel alteration. The worst (lowest) of the left and right bank stability EII scores are used in the calculation as follows:

Problem Score = 100 – ¾*bank stability EII – ¼*channel alteration EII

7.4.9 Altered Hydrology: Current

Altered hydrology is a problem that includes both lack of baseflow and flashiness in response to runoff events. Flashiness refers to the slope of a hydrograph when there is a steep rising and falling, with a shorter time from the peak of the storm to the end of the storm, where the storm event goes from a low peak and extended baseflow to a high peak with no baseflow. Flow is most likely the best predictor of future environmental conditions and can be predicted with reasonable accuracy with SWAT models, even in watersheds without continuous flow monitoring. Because aquatic life communities rely on healthy flow regimes, hydrology is a good and logical predictor of aquatic life integrity.

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The current Altered Hydrology problem score method was developed from a multiple linear regression of EII aquatic life scores versus a set of metrics describing the flow regime of the reach (Glick et al., 2009). The formula, derived from the coefficients of the regression analysis, uses selected flow metrics calculated from mean daily flow records as follows:

$$\textbf{Problem Score} = 71.321 - 0.896 * F_{Ln} + 3.675 * \ln(Q_{90})$$

Where:
F_{Ln} = Average number of times mean daily flow is < 0.1 ft3/s (Ritcher et al., 1989)
Q_{90} = Daily flow rate exceeded 10% of the time, or the 90th percentile

Final SWAT models needed to generate these scores are not complete at the time of this writing. When available, flow metrics will be calculated from the output of SWAT models for all reaches for a predetermined length of time preceding the evaluation year.

7.4.10 Altered Hydrology: Future

The future problem score is simply the difference between the future Altered Hydrology problem score, calculated using the SWAT models incorporating predicted future land use and the current Altered Hydrology problem score, as follows:

Problem Score = Future Altered Hydrology Prob. – Current Altered Hydrology Prob.

Highest priority reaches would be those existing, stable flow regimes which are predicted to exhibit future flow regimes that lack baseflow and are more flashy in response to runoff events.

7.4.11 Problem Scoring Methodology

Individual problem scores for each of the above ten systems is scaled so that the minimum problem score equals 0, the maximum (or worst) problem score equals 100, and all intermediate scores are linearly scaled accordingly. Scaling is done separately for each problem. Scaling aids in data interpretation, preserves the rank order of reach problems, and is consistent with both the EII format and the scoring procedures used by the flood and erosion missions. Although scaling creates a “moving target”—changing from year-to-year—the problem scores are not intended to be used to measure solution success. The positive or negative impacts of solutions are to be measured using either the raw (unscaled) problem score or directly by EII scores.

7.4.12 Water Quality CIP Problem Scores

Problem scores may be combined as necessary for use in the mission integration process. For Capital Improvement Program (CIP) uses in relation to the mission integration purposes, four measurements

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that can be feasibly addressed by stormwater treatment capital projects are combined into a CIP water quality score. These four components are:

- Poor Riparian Vegetation;
- Unstable Channels;
- Nutrients (non-sewage); and
- Toxins in Sediment

These scores are added together and scaled from 0-100 to generate the CIP problem score. This score will include Altered Hydrology in the future once SWAT model efforts have been completed. Table 7.3-3 and Figure 7.4-1 show the water quality CIP problem scores by EII reach. The colors in Figure 7.4-1 represent problem score narrative ratings, which are assigned based on CIP problem score ranges (see Table 7.4-2 below). The CIP problem score narrative ratings are distinct from the EII narrative ratings discussed in Section 7.3. Predictably, the urban core, which has been largely developed prior to the advent of Austin's protective watershed regulations, has a disproportionate share of the higher problem severity scores.

Table 7.4-2 Water Quality CIP Problem Scores and Narrative Ratings

CIP Problem Score	Narrative Rating
75 - 100	Very High
50 - 75	High
25 - 50	Medium
0 - 25	Low

Figures 7.4-2 and 7.4-3 present the distribution of Water Quality CIP Problem Scores by rank. Unlike the problem scores for the other missions, the Water Quality CIP Problem Score is gradually distributed, with a roughly equal number of reaches in each narrative score range (e.g., Very High, High, etc.; see Figure 7.4-2). Rather than a few very severe problems, the Water Quality distribution has a number of moderately severe problems. For example, there are 6 scores over 90 and 17 over 80. (For comparison, Creek Flood structure clusters and Erosion Control reaches both have one score each of 100 and no scores thereafter over 50)

Table 7.4-3 lists the EII reaches with the Top 20 ranked Water Quality CIP Problem Scores, the first 20 of which are also identified as the Top 20 Priority Problem Areas for use in the Mission Integration and Prioritization (MIP) planning process (See Section 10 for more information regarding the MIP process). The most severe water quality problems are currently found in Waller, Harpers, and Buttermilk Branch watersheds. This is unsurprising given their position in or near the urban core, where the majority of development occurred prior to the advent of Austin's protective watershed regulations. Other Urban watershed EII reaches (East Bouldin, Little Walnut, Shoal, Johnson, and Blunn) also currently yield poor water quality scores. Most Urban watersheds feature a combination

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of uncontrolled urban runoff from pavement and roofs (leading to unstable channels); land uses more likely to generate high levels of pollutants, poor riparian zone width and condition; and generally lack structural water quality controls for most development that might otherwise control nutrients and toxins. All of these factors contribute to poor Water Quality CIP Problem Scores. Additionally, a small number of non-Urban creeks are also found on this Top 20 list, such as Taylor Slough South and Dry Creek North (both heavily built out prior to water quality regulations, resembling Urban watersheds in many ways), and Lake Creek (heavily built out with poor riparian zone conservation and wastewater infrastructure concerns). Other non-Urban creeks in far east or southeast Austin also make the Top 20 list—Cottonmouth, Rinard, Marble, and North Fork Dry —largely due to poor baseflow and degraded, compromised stream channels and riparian zones following years of agricultural land management.

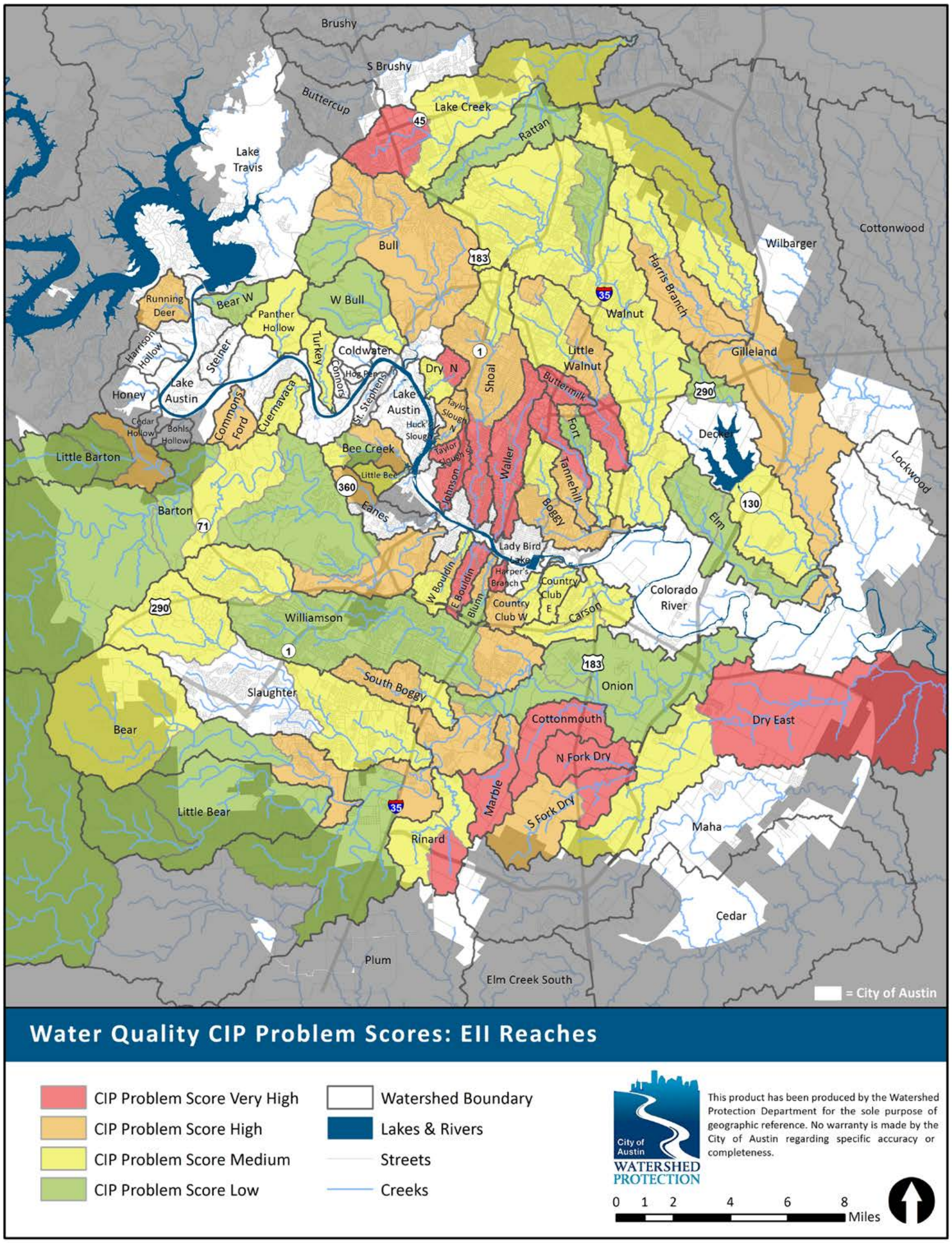

Figure 7.4-1 Map of Water Quality CIP Problem Scores by Sampling Reach (October 2015)

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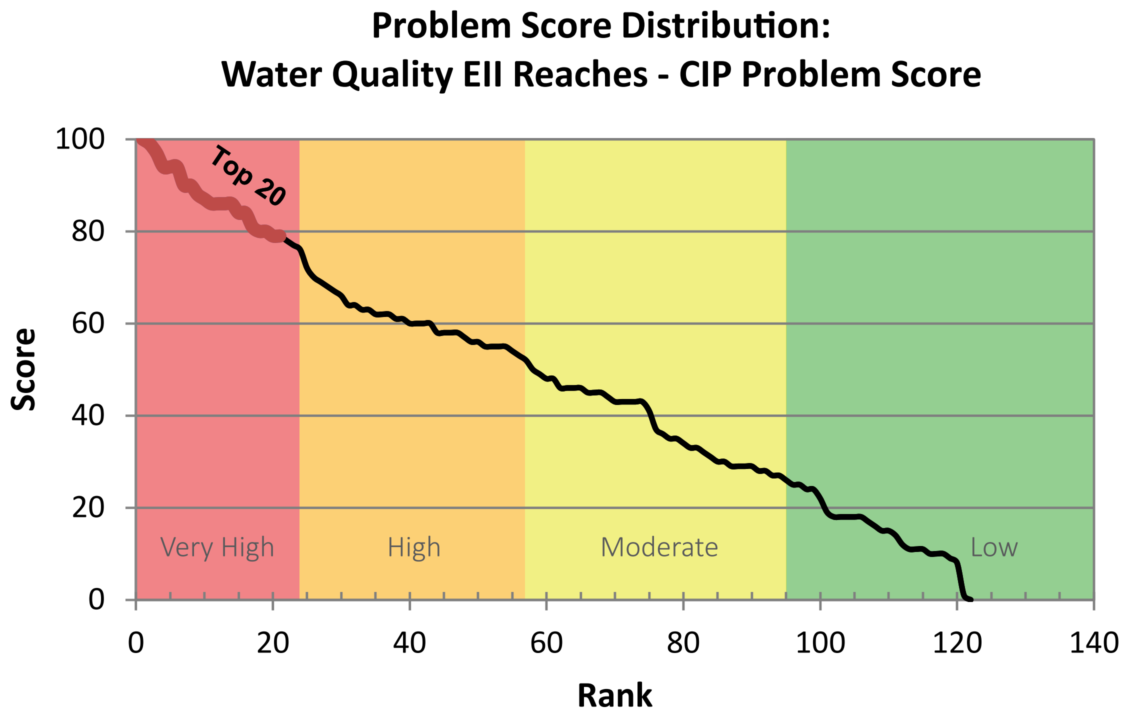

Figure 7.4-2 Problem Score Distribution: All CIP Problem Scores (October 2015)

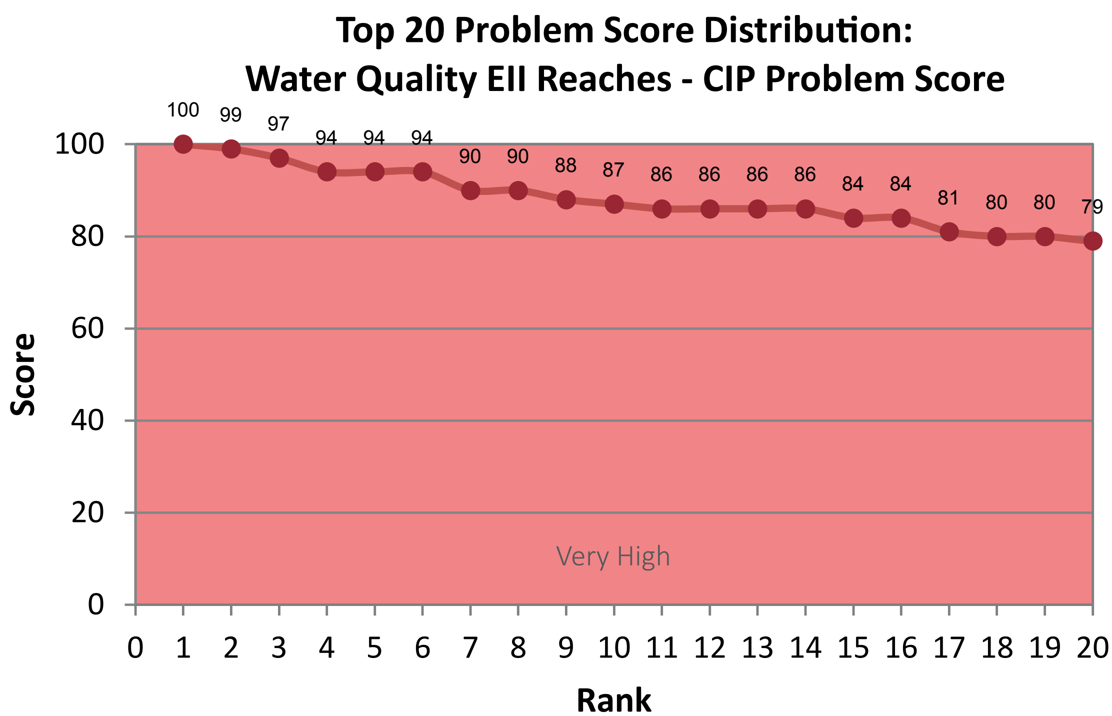

Figure 7.4-3 Problem Score Distribution: Top 20 CIP Problem Scores (October 2015)

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Table 7.4-3 Top 20 Ranked Problem Scores: EII Reaches (October 2015)

Rank	Probem Area Name (EII Reach)	Watershed	Score
1	WLR1	Waller	100
2	HRP1	Harpers Branch	99
3	BMK3	Buttermilk Branch	97
4	CTM1	Cottonmouth	94
4	BMK1	Buttermilk Branch	94
4	BMK2	Buttermilk Branch	94
7	WLR3	Waller	90
7	SHL2	Shoal	90
9	RIN3	Rinard	88
10	MAR2	Marble	87
11	LKC3	Lake	86
11	DRN2	Dry Creek North	86
11	NFD1	North Fork Dry	86
11	WLR2	Waller	86
15	EBO2	East Bouldin	84
15	TAN3	Tannehill Branch	84
17	EBO1	East Bouldin	81
18	DRE1	Dry Creek East	80
18	JOH1	Johnson	80
20	TYS1	Taylor Slough South	79
20	SHL1	Shoal	79

7.5 Results

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The change in percentage of watersheds within EII narrative categories by assessment period indicates some fluctuation over time, especially in response to meteorological drought conditions. In the 2013-2014 assessment period, 55% of watersheds scored “Good” or better in overall EII score. Only 38% of watersheds assessed in the initial EII data collection (1996-1999) yielded “Good” or better overall scores. Current EII scores by reach indicate that the worst problem areas fall within the central urban core or in the eastern Blackland Prairie ecoregion, with the exception of Lake Creek (see Figure 7.3-2). EII scores for all EII reaches are calculated annually using the most up-to-date field sampling data (see Table 7.5-1). Hydrology problem scores will be calculated once SWAT models have been constructed and calibrated for all watersheds.

Problem scores are derived from Environmental Integrity Index (EII) monitoring and change annually as new EII data are collected. The following general summary of water quality problem areas was derived from 2013-2014 monitoring data:

- *Bacteria from Animals*. Elevated levels of fecal indicator bacteria, most likely originating from domestic pets and wildlife, are observed primarily in the urban core, particularly in Shoal Creek upstream of 15th Street. Potential animal waste problems also appear to cluster in South Boggy, Eanes, Bull, West Bull, and Blunn Creeks.

- *Construction Runoff.* Bee Creek in West Austin, lower Shoal Creek, Panther Hollow, and Boggy Creek indicate high problem scores for construction sediment runoff, indicating elevated levels of suspended sediments in areas with relatively stable creek cross sections. High scores typically occur in areas with significant levels of new and redevelopment activity.

- *Nutrients (Non-Sewage)*. Elevated levels of nutrients from nonpoint sources not including leaking wastewater infrastructure are observed primarily in areas with suburban development patterns, mostly notably with extensive areas of managed lawn turf and other landscaping. Elevated nutrients in these areas may be the result of heavy fertilizer use. Stream systems in Bear, Lake, Slaughter, and multiple Lake Austin tributaries have elevated nutrient problems not primarily related to wastewater. Although Gilleland Creek has high nutrient problem scores, this is an artificial result of treated wastewater effluent discharged to the creek.

- *Litter*. Litter problems are generally most evident in the urban core, most likely as a result of the high population density and associated human activity. Lower Tannehill Branch and lower Waller creeks have very high litter problem scores. High litter problem score values were also observed in Dry Creek East and upper Decker outside the urban core.

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- *Poor Riparian Vegetation*. Poor quality and quantity of vegetation in riparian areas adjacent to creeks are most strongly indicated throughout the urban downtown core north of the Colorado River. This pattern is often associated with close and longstanding encroachment and vegetation management practices by adjacent development. Additionally, poor riparian vegetation scores are observed in upper Gilleland, Harris Branch, and Lake creeks near Pflugerville and Cedar Park.

- *Toxins in Sediment*. Elevated levels of toxins in sediment are most evident in Harpers Branch and throughout the Bull Creek watershed. These elevated levels are related to increased concentrations of polycyclic aromatic hydrocarbons (PAHs) and pesticides relative to aquatic life effect concentrations.

- *Sewage*. High severity problems with leaking infrastructure are scattered throughout Austin, with the highest scores in Taylor Slough South, lower Shoal, and Buttermilk. The distribution of these problems may be a function of wastewater infrastructure age.

- *Unstable Channels*. Stream stability problem scores are generally clustered in the urban core where most development preceded the advent of watershed protection regulations designed to control hydrologic flows from new and redevelopment. However, high stability problem scores were also observed east of IH-35 and south of the Colorado River in Cottonmouth and South Fork Dry creeks. The southeastern cluster may be related to hydrologic changes from increasing development having a disproportionate impact on these Blackland Prairie creeks with deep soils.

Table 7.5-1 Individual Problem Scores by EII Reach (October 2015)

EII Reach	Bacteria from Animals	Construction Runoff	Nutrients	Litter	Poor Riparian Vegetation	Toxic Sediment	Bacteria from Sewage	Unstable Channel	CIP WQ Problem Score
BAR1	31	63	69	5	28	31	87	28	52
BAR2	51	67	49	5	28	31	24	16	15
BAR3	33	54	67	0	36	31	7	17	33
BAR4	52	70	48	5	37	31	22	6	12
BAR5	44	66	56	0	0	31	23	8	18
BAR6	83	84	17	0	40	31	33	6	15
BEE1	41	77	59	13	76	45	29	23	58
BEE2	52	100	48	0	52	45	42	15	9
BEE3	49	50	51	13	80	45	69	60	30
BER1	0	57	100	53	28	45	61	42	56
BER2	Not sampled in last cycle due to dry conditions								24
BER3	57	44	43	67	58	45	19	36	36
BLU1	95	53	5	53	86	38	59	53	57
BLU2	56	61	44	53	84	38	90	28	70
BLU3	71	60	29	11	30	38	69	27	22
BMK1	73	20	27	84	99	53	73	83	94
BMK2	0	41	0	68	82	53	0	44	94
BMK3	44	22	56	79	100	53	100	81	97
BOG1	35	42	65	79	82	13	16	98	69
BOG2	76	45	24	74	99	13	56	73	58
BOG3	68	95	32	58	90	13	80	17	48
BRW1	71	70	29	7	10	53	29	4	11
BUL1	97	0	3	33	60	100	49	100	72
BUL2	40	38	60	13	73	100	30	47	61
BUL3	79	82	21	0	30	100	23	0	25
BUL4	58	81	42	13	20	100	72	32	64
BUL5	18	80	82	7	0	100	75	4	62
CAR1	61	71	39	27	37	21	99	30	26
CAR2	82	94	18	13	95	21	79	13	46
CCE1	0	65	0	5	0	45	0	0	29
CCW1	61	45	39	89	64	24	0	83	29
CCW2	92	32	8	37	94	24	41	86	63
CMF1	51	90	49	80	80	34	21	17	58
CRN1	22	84	78	7	52	39	69	15	43
CTM1	19	46	81	40	84	34	64	91	94

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Table 7.5-1 continued

EII Reach	Bacteria from Animals	Construction Runoff	Nutrients	Litter	Poor Riparian Vegetation	Toxic Sediment	Bacteria from Sewage	Unstable Channel	CIP WQ Problem Score
DKR1	62	57	38	0	85	3	29	53	41
DKR3	55	71	45	100	46	3	70	38	11
DRE1	18	73	82	100	92	47	89	62	80
DRE2	46	75	54	93	72	47	58	45	45
DRN1	91	78	9	80	30	97	44	8	43
DRN2	Not sampled in last cycle due to dry conditions								86
EAN1	Not sampled recently due to dry conditions								None
EAN2	99	87	1	13	82	97	66	9	62
EBO1	58	0	42	84	79	46	61	92	81
EBO2	45	35	55	68	82	46	98	64	84
EBO3	88	40	12	58	88	46	22	69	67
ELM1	0	73	0	32	46	49	0	31	11
ELM2	0	45	0	58	52	49	0	28	18
FOR1	0	41	0	79	52	23	0	86	37
FOR2	0	28	0	53	88	23	0	72	27
FOR3	0	65	0	26	82	23	0	17	10
FOR4	63	67	37	53	96	23	76	34	60
GIL1	17	57	83	53	28	13	95	53	53
GIL2	0	71	100	5	37	13	87	34	55
GIL3	14	55	86	37	68	13	98	53	56
GIL4	46	69	54	16	90	13	44	34	32
GIL5	12	42	88	53	90	13	99	75	45
GIL6	35	30	65	11	97	13	96	73	45
HRP1	49	28	51	63	99	100	96	84	99
HRS1	27	56	73	53	90	0	96	52	54
HRS2	45	67	55	58	96	0	99	38	44
HUK1	Not sampled recently due to dry conditions								None
JOH1	29	41	71	5	100	24	85	92	80
LBA1	51	59	49	7	60	34	28	17	63
LBA2	42	73	58	0	20	34	51	19	14
LBA3	64	81	36	0	20	34	36	0	18
LBE1	Not sampled in last cycle due to lack of habitat								29
LBR1	53	90	47	0	19	47	35	0	10
LBR2	0	85	0	0	28	47	0	15	8
LKC1	78	51	22	67	10	39	48	34	29

Table 7.5-1 continued

EII Reach	Bacteria from Animals	Construction Runoff	Nutrients	Litter	Poor Riparian Vegetation	Toxic Sediment	Bacteria from Sewage	Unstable Channel	CIP WQ Problem Score
LKC2	81	87	19	67	10	39	26	0	35
LKC3	9	56	91	67	100	39	63	51	86
LWA1	55	30	45	89	91	15	23	81	76
LWA2	33	53	67	79	52	15	48	34	55
LWA3	81	59	19	58	84	15	41	27	46
LWA4	85	37	15	53	91	15	67	67	64
MAR1	51	79	49	27	28	47	88	45	55
MAR2	50	69	50	67	90	47	20	60	87
NFD1	43	59	57	67	92	32	62	83	86
ONI1	53	79	47	7	40	24	70	36	19
ONI2	75	71	25	20	60	24	48	64	24
ONI3	55	66	45	20	60	24	79	25	60
ONI4	64	52	36	0	44	24	53	34	10
ONI4a	Not sampled recently due to dry conditions								None
ONI5	61	64	39	0	20	24	21	11	0
ONI6	74	70	26	0	10	24	31	11	1
PAN1	38	98	62	47	44	76	47	2	50
RAT1	0	80	0	27	100	87	0	49	18
RAT2	0	65	0	20	40	87	0	17	16
RDR1	61	70	39	7	84	61	97	15	68
RIN1	81	46	19	73	58	0	38	85	43
RIN2	67	71	33	27	88	0	0	28	35
RIN3	Not sampled in last cycle due to dry conditions								88
SBG1	71	91	29	67	64	84	37	25	49
SBG2	100	79	0	80	76	84	69	36	61
SFD1	49	69	51	13	90	24	89	72	77
SFD2	61	73	39	27	82	24	29	89	62
SHL1	44	100	56	84	88	63	100	39	79
SHL2	85	4	15	11	94	63	58	89	90
SHL3	75	54	25	47	88	63	41	34	66
SHL4	100	61	0	53	88	63	50	41	43
SLA1	35	85	65	80	20	37	51	4	30
SLA2	Not sampled recently due to dry conditions								None
SLA3	16	79	84	0	64	37	74	19	48
TAN1	45	50	55	100	46	58	47	64	60

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Table 7.5-1 continued

EII Reach	Bacteria from Animals	Construction Runoff	Nutrients	Litter	Poor Riparian Vegetation	Toxic Sediment	Bacteria from Sewage	Unstable Channel	CIP WQ Problem Score
TAN2	84	54	16	68	91	58	48	56	78
TAN3	78	32	22	47	86	58	66	67	84
TRK1	50	77	50	7	19	50	34	2	31
TYN1	5	75	95	13	20	50	72	15	55
TYS1	58	91	42	27	68	95	100	23	79
WBL1	95	78	5	67	65	50	58	15	28
WBL2	83	90	17	73	19	50	45	13	17
WBO1	75	69	25	79	64	46	63	20	34
WBO2	54	53	46	53	82	46	86	36	58
WBO3	69	68	31	32	72	46	44	8	46
WLN1	46	31	54	21	37	16	10	72	46
WLN2	43	51	57	21	52	16	52	50	43
WLN3	75	38	25	37	58	16	48	44	27
WLN4	45	39	55	68	60	16	93	50	28
WLN5	72	73	28	16	84	16	46	2	18
WLR1	39	25	61	95	97	94	93	100	100
WLR2	51	59	49	58	96	94	94	48	86
WLR3	63	63	37	47	95	94	84	44	90
WMS1	29	63	71	26	40	14	72	56	60
WMS2	38	42	62	74	10	14	50	42	25
WMS3	62	73	38	32	64	14	35	14	33

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8 Data Collection and Evaluation

This Master Plan is founded on an integrated planning process for watershed protection. This integrated planning approach calls for the joint development of flood, erosion, and water quality management strategies. The success of the Master Plan relies heavily on WPD's ability to coordinate data collection and evaluation methods within and across the three missions of WPD.

The data necessary to characterize watershed problems is described in the following sections. In addition, detailed watershed data is contained in each of the specific reports generated by the various project teams.

8.1 Information Management Plan

In 1998, the City commissioned a study performed by the Camp Dresser & McKee (CDM) engineering firm which assessed the Information Technology (IT) needs of the various missions at the time. The study examined the current state of the information systems, datasets, and applications needed and provided recommendations on key areas which needed to be further developed. Many of these recommendations were immediately actionable. However, the infrastructure necessary to support others was not in place.

In 2006, the Watershed Protection Department revisited the recommendations in the 1998 CDM report to gauge successes and failures, and provide a relatively short-term (five to seven year) road map for the future. The Information Management Plan (IMP) development process began with detailed interviews with every section of the Department to determine strengths, weaknesses, and common needs of all department sections and compare them against current best practices to develop a set of recommendations. Based on these recommendations, WPD allocated resources to its Data Management section and charged it with turning these recommendations into a practical business plan. The plan includes staffing needs, Capital Improvement Program (CIP) project development and management, and base dataset development. The IMP highlights three major projects which are critical to providing the IT infrastructure needed to support the Master Plan's continued analytical efforts: establishment of a Data Management infrastructure, completion of the Drainage Infrastructure GIS project, and completion of the Work Order Management System (WOMS) project.

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8.2 Data Management

Establishing a data management infrastructure for the department was the first major recommendation in the IMP. Out of the interviews that were performed with staff during the IMP creation, several common themes emerged:

- The Department had a need for a larger amount of diverse data;
- Different work groups often needed the same types of datasets;
- No clear data standards had been established for the creation and maintenance of data;
- Duplicate or similar data was often being collected by disparate work groups;
- Major gaps existed in the Department's data inventory, hardware infrastructure, and application arsenal; and
- Existing staff lacked the resources and skills to deal with these issues.

To address these needs, the Data Management section hired staff with the experience and knowledge necessary to establish the Department's enterprise architecture. Data needs had been cataloged as part of the IMP process and a matrix developed which documented each work groups need for each dataset. The IMP outlined a procedure for documenting these datasets in a thorough and consistent fashion. The datasets were grouped, committees were established to make decisions about each dataset, and work was initiated. To support the data development efforts, a central spatial database server environment (production and test) was purchased and deployed. A broad set of spatial data developers was identified and given basic training in the tools and technologies needed to build and sustain an enterprise spatial library.

To meet more advanced needs, a Geographic Information Systems (GIS) programmer was hired to address individual department GIS programming needs more efficiently than relying upon the centralized City IT GIS programming staff. Other key staff positions were put in place to address spatial database administration and planning, as well as enterprise application support (Amanda, GIS, Computerized Maintenance Management System). All of these efforts are coordinated within the department by way of the GIS/Database Power Users Group. In addition, department IT activities are coordinated at the City level to ensure that City standards are maintained, that development across departments is coordinated, and that resource requirements are stated.

Finally, recommendations from the IMP were developed into CIPs where necessary. Major projects include the Drainage Infrastructure GIS project, Work Order Management System project, Mobile Computing initiatives, and the implementation of a Document Management System.

All of these tasks are necessary to develop the IT infrastructure and data inventory needed to support the various needs of the department and, in particular, the Master Plan process used to coordinate the actions of the various missions.

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8.3 Drainage Infrastructure GIS (DIG)

The Drainage Infrastructure GIS (DIG) is a comprehensive Geographic Information System (GIS) representing the physical drainage assets owned and maintained by WPD, including storm drain pipes, inlets, culverts, manholes, and ditches. The project is essential to many different departmental needs, including mapping, work order and maintenance tracking, hydraulic models, emergency spills response, and spatial analysis. A major project to complete this dataset is ongoing and scheduled for completion in 2017.

The DIG is part of much broader effort to depict an overall stormwater conveyance system. It will eventually represent not only the physical inlets and pipes that stormwater enters and flows through, but also the related features which connect the physical assets including managed channels, ponds, creeks, and other features which, when combined, create a network of features which can be used for upstream and downstream tracing. This capability could be utilized by groups such as Pollution Prevention to determine which creek or pond an industrial spill will travel to if it entered the stormdrain system. Other ancillary datasets, such as erosion control structures or sampling site locations, will round out the conveyance system to provide a complete picture of the Department's assets.

8.4 Computerized Maintenance Management System (CMMS)

A major use for the DIG is to populate the asset inventory within a Computerized Maintenance Management System (CMMS), still frequently referred to by its original name: Work Order Management System (WOMS). It is the second of three major projects highlighted by the IMP. When completed, the WOMS project will provide a multitude of functionality:

1. Track asset descriptors such as condition, status codes, criticality, reliability, expected lifetime, and warranty information;
2. Track work orders created against assets including failure codes, work types performed, status codes, work priority, consumption of labor and materials, costs, and labor/equipment/materials reservation;
3. Schedule and track preventive maintenance activities including inspections, check lists, and instruction lists;
4. Maintain a dynamic inventory including materials and parts, stock levels and locations, valuation and descriptions; and
5. Associate safety plans with job types including necessary permits, staff training needs, certifications, organization of Material Safety Data Sheets (MSDS), and job process documentation.

The major users of this application for day-to-day use are from the Field Operations division. However, several other WPD sections have begun using the application including

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Stream Restoration, Field Engineering Services, Pollution Prevention and Spill Response, and Commercial Pond Inspection. Additional WPD sections have been identified as potential users including Local Flood and the Floodplain Office. Many Legacy databases and datasets have been cleaned and migrated to the CMMS and more that are currently used by staff are in the planning stages to migrate into the CMMS.

A CMMS functions best when integrated with GIS. The GIS component standardizes data collection, speeds asset identification in the field, and enables complex analysis of maintenance data. For example, information derived from the CMMS can be used to provide maintenance trends within a geographic area or on a particular combination of pipe material and age range. Such information could guide the cost-effective prioritization of rehabilitation and replacement CIP projects.

IBM's Maximo Asset Management system was chosen as a citywide solution for Enterprise Asset Management (EAM), of which CMMS is a subset. This system was successfully implemented in 2011 with WPD as one of the user departments. Additional capabilities for WPD have been added since beginning to meet the needs identified in the IMP.

Section 9

9 Inventory of Potential Solutions

9.1 Overview

After the Phase 1 problem assessments were completed, the Master Planning effort then focused on the task of developing integrated solutions for identified flood, erosion, and water quality problem areas. An "integrated" solution refers to the ideal situation where a proposed solution would effectively promote the attainment of each of the watershed protection goals for a targeted location. This initial effort conducted in the 2001 Master Plan has been updated in this report using information from current problem assessments as well as updated information on potential solutions.

An inventory of all available solution types was needed to document the range of potential solution types, their general levels of effectiveness, their cost, and other implementation considerations. Potential solutions include all capital solutions, programs, and regulations currently used by Watershed Protection as well as additional solutions identified through benchmarking efforts that have potential to address identified watershed problems. To compile the complete inventory of solution types, information was gathered on various controls from a variety of sources including the City of Austin, Lower Colorado River Authority, Center for Research in Water Resources (CRWR), and other local/state/national resources. Solutions were grouped into three categories:

- **Capital Projects** – commonly involve the construction or improvement of infrastructure
- **Operating Programs** – Drainage Charge funded watershed protection activities implemented by City staff and funded through the operating budget (e.g., storm drain system maintenance)
- **Regulations** – involve the application and enforcement of City codes and rules (e.g., drainage design criteria)

This section presents an inventory of watershed management solutions considered for use during the Master Plan. Not all the potential solutions included in this inventory were selected as Master Plan solutions. Sections 10 and 11 describe the solution selection process, and present the solution recommendations. The inventory describes the basic characteristics of available capital project technologies, operating programs, and regulations.

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9.2 Inventory of Capital Project Solutions

Capital projects are those involving construction of City-owned infrastructure elements such as storm drain systems, stormwater controls, and purchase of land. These typically involve engineering design, construction plans development, bidding services, and construction. Capital projects are best used to solve existing problems such as: (1) Type 1 and 2 erosion, (2) flooding of the creek and local drain system, (3) existing floodplain development, (4) existing storm drain conveyance, and (5) several aspects of water quality problems including degraded riparian zones.

The Capital Projects Inventory presents options that involve construction of structural elements or controls. The solutions presented here are grouped under one of the three WPD missions. Capital projects are commonly funded using bond monies, transfer of WPD's normal operating funds, as well as other sources such as the Urban Watershed Structural Control Fund and the Regional Stormwater Management Program (RSMP) Fee.

9.2.1 Flood Mitigation Capital Projects

Flood Mitigation capital projects are grouped into two categories: (1) nonstructural solutions and (2) structural solutions. Nonstructural solutions focus on removing structures (e.g., homes, businesses) from flood prone areas. Structural solutions focus on either storing or diverting flood flows, or conveyance improvements.

9.2.1.1 Property Acquisition for Flood Mitigation

Nonstructural flood mitigation strategies are those which do not involve the construction of facilities or structures intended to reduce flood damage. Since the late 1960s, flood mitigation efforts across the U.S. have shifted away from "hard" structural solutions and toward nonstructural solutions. The Federal Emergency Management Agency (FEMA) has in recent years promoted the removal of homes and even entire communities from flood-prone areas. This approach can also satisfy "multi-objective" floodplain management strategies, in that the land acquired can be used for public recreation and as a natural buffer to protect riparian ecosystems.

In order to acquire property for flood mitigation, the City procures an independent appraisal of the property, offers fair market value to the owners, and provides relocation assistance for all displaced owners and tenants. One condition of receiving relocation benefits is that displaced owners and tenants must relocate to areas outside of a flood hazard zone. The entire acquisition and relocation process can take many months (or even years) to accomplish, especially for large-scale projects.

9.2.1.2 Structural Flood Mitigation Solutions

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Structural solutions are engineered modifications to waterways designed to reduce flood risk. Unlike buyouts, they may offer the option of leaving existing development in place. They can be used in combination with nonstructural buyout strategies to gain a lower-cost solution to a flooding problem. The technologies presented in this section are assumed to be implemented on a regional or large-scale basis and, as such, they are generally more effective than multiple privately-owned, smaller-scale applications. The structural controls included in this inventory are shown in Table 9.2.1-1.

Table 9.2.1-1 Inventory of Structural Flood Mitigation Solutions

Inventory of Structural Flood Mitigation Solutions	
Flood Detention	Storm Drain System Upgrades
Underground Ponds	Structure Raising
Channel Modification	Low-Water Crossing Upgrades
Flow Diversion	Removal of Constrictions
Levees and Floodwalls	

Flood Detention

Detention ponds are structures that capture and hold storm runoff for a limited period of time. They are designed to store flows during the most critical part of the flood and release the stored water as the flood subsides. While detention does not reduce the total volume of runoff from a flood event, it does reduce the peak flow rate and peak water depths, thus reducing flood risks downstream. Large-scale flood detention projects also offer the opportunity for customized design of the inflow and outflow structures, allowing for multiple-use application of the facility.

The principal design considerations for detention ponds are storage volume and the size of inlet and outlet structures. The inlet regulates the rate of stormwater inflow. The flood storage volume is usually created by excavation, enclosing an open area with earthen berms or structural walls. The outlet structure restricts outflow rates to acceptable levels, assuming the storage volume is large enough to store the difference between the rate of flow into and out of the pond. There are two basic configurations for detention ponds: on-line and off-line. On-line ponds are positioned directly in the flowpath with all flow, including flood flows, passing entirely through the facility. Figure 9.2.1-1 presents a photograph of a typical on-line detention facility in Bull Creek.

Off-line detention ponds are located out of waterways, often within the upper portion of the watershed. Off-line detention ponds remain empty until flood flows reach critical levels, when excess flood flows are diverted into the detention pond. After the flood recedes, the stored volume

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drains into the channel. Northwest Park, in the Shoal Creek watershed is an example of effective dual-purpose application of an off-line regional facility. Figure 9.2.1-2 shows the Northwest Park off-line detention facility.

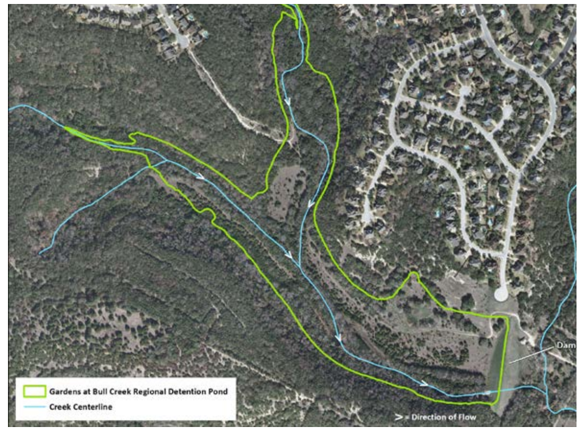

Figure 9.2.1-1 Typical on-line flood detention facility

Figure 9.2.1-2 Off-line detention facility at Shoal Creek at Northwest Park

Underground Ponds

As land values increase, underground detention and sedimentation ponds gain in popularity because they allow for a secondary use, such as parking, on top of the detention facility. Advantages to this type of system is that it allows for multiple benefits from a small, urbanized property, and can be constructed with concrete vaults or pipe systems. Figure 9.2.1-3 shows an underground pond, and common maintenance concerns.

Figure 9.2.1-3 Underground pond on S. Pleasant Valley Rd: Grates are difficult to access, and must be removed in order to access trash in vault below

Disadvantages include the requirement for frequent maintenance with restricted access. To offset concerns over the long-term maintenance of underground ponds, revisions have been made in recent years to include minimum design standards for underground ponds in the Drainage Criteria and Environmental Criteria Manuals (Sections 8.5 and 1.6.2, respectively). Changes include establishing minimum dimensions, access standards, and the requirement for a maintenance plan, which is recorded in the public records as part of a restrictive covenant. The restrictive covenant also includes an annual maintenance certification by a licensed engineer, which is sent to WPD. Additional potential improvements for consideration regarding underground ponds would include charging an annual fee to include routine inspection as part of an operating permit program.

Channel Modification

Channel modification can increase flow capacity (conveyance) by changing the existing waterway geometry and/or cross-section. Increased capacity reduces water depths and the potential for flooding. Channel modification may be accomplished using the same side slope revetment techniques used for erosion control projects. To the extent that more natural channel revetment technologies are employed, the adverse environmental impacts are reduced. Figure 9.2.1-4 presents a channel modification project on Fort Branch Creek.

Figure 9.2.1-4 Channel Modification using natural revetment on Fort Branch Creek.

Flow Diversion

Flow diversion, such as channels and tunnels, directs a portion of the peak flood flow to an alternate path. Excess flows are carried on-line or off-line, either along an open channel diversion or through a closed pipe (tunnel) path. The diversion may rejoin its original channel or proceed to a different location. On-line systems divide all flow between two paths. Off-line systems pass all flow through the original path until a specified flood elevation is reached, when a control diverts excess flow to the diversion path.

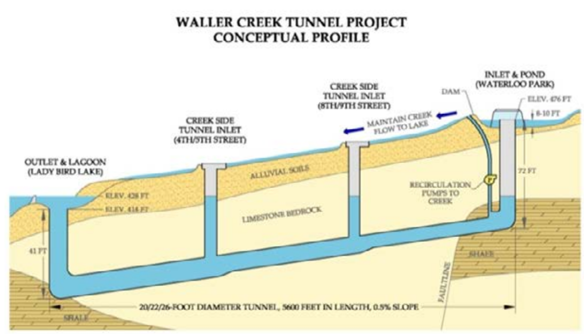

Figure 9.2.1-5 Waller Creek Tunnel (Source: Kellogg Brown & Root Services and Espey Consultants, 2008)

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Open channel diversions require sufficient space in the overall flood conveyance path. Diversion tunnels can be built deep below the ground surface but are quite expensive. Figure 9.2.1-5 represents a conceptual profile of the Waller Creek Tunnel.

Storm Drain System Upgrades

Storm drain system upgrades consist of replacement or renovation of the existing storm drain system. This capital project solution is an extension of the Storm Drain Rehabilitation program. This flood mitigation approach targets localized nuisance flooding caused by inadequately sized or structurally degraded storm drains. Upgrades are made in response to storm drain system inspections, citizen complaints, and/or updated modeling of the system.

Structure Raising

"Structure raising" physically removes threatened structures from the floodplain by elevating them with fill material or some form of piers, posts, or columns. In most cases, floodplain regulations will not allow the use of fill materials if they impair floodplain conveyance. The use of piers, posts, or columns typically will not significantly impact floodplain conveyance or flood elevations.

Low-Water Crossing Upgrades

Upgrade of a low-water crossing aims to alleviate flooding risk of a roadway at creek crossings and most commonly elevates a roadway above the modeled flood elevation. Improvements may include the construction of a new higher bridge, addition of new culverts, or replacement of existing pipes or culverts, increasing stormwater conveyance beneath the structure. Figure 9.2.1-6 depicts a low water crossing upgrade at Slaughter Creek and David Moore Drive, completed in 2014. This project met current Drainage Criteria Manual requirements, elevating the roadway so that a 100-year storm would not overtop the crossing more than six inches, as modeled under fully-developed conditions.

Figure 9.2.1-6 Low-water crossing upgrade at David Moore Drive and Slaughter Creek.

Removal of Structural Constrictions

Culverts, bridges, low water crossings, and other structures often create local constrictions in streams. The originally designed conveyance through these structures may not be adequate and energy losses associated with the constriction cause increased flooding upstream. Replacing undersized structures or removing constrictions reduces upstream water surface elevations. This approach is best applied where a structure constriction is creating local flooding and/or scour.

Levees and Floodwalls

Levees and floodwalls are man-made barriers that prevent flood waters from spilling into flood-vulnerable areas. Figure 9.2.1-7 depicts a floodwall that was constructed in the Crystalbrook neighborhood in Walnut Creek. Floodwalls are generally constructed using masonry block and poured concrete, and require substantial lateral footings and steel reinforcement. Levees and floodwalls are most applicable where floodwaters encroach upon structures, but the overbank region (where structure is located) is not required for local conveyance.

Figure 9.2.1-7 Floodwall in Walnut Creek

9.2.2 Erosion Control Capital Solutions

Erosion Control solutions include both projects funded through the Capital Improvements Project budget, and solutions implemented by in-house erosion crews (discussed in Section 9.3, Operating Programs). These solutions typically focus on reinforcing the stream channel at actively eroding stream banks or slowing the velocity of flow using stream restoration design or grade controls. Although projects are driven by the need to prevent the loss of property (land or structure) to erosion, solutions aim to also increase ecological function and avoid or decrease flood hazards. In addition to in-stream projects, passive solutions such as property acquisition and riparian restoration are also considered to remove a potential erosion hazard and provide a buffer where the natural stream processes are allowed to occur without impacting community resources. The erosion control solutions presented include:

Table 9.2.2-1 Inventory of Structural Erosion Control Solutions

Inventory of Structural Erosion Control Solutions	
Property Acquisition	Reach-Based Stream Restoration
Local Stabilization Techniques	Stormwater Detention

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9.2.2.1 Property Acquisition for Erosion Control

Properties and structures vulnerable to erosion may be removed from the threat of erosion through direct acquisition of land or structures in the problem area. After structures are removed, the riparian zone along the creek within the acquired area can be restored by establishing a Grow Zone and/or an active native vegetation installation and management plan.

9.2.2.2 Local Stabilization Techniques

Local stabilization includes a variety of techniques that directly reinforce the channel erosion control in limited areas in the stream system. They are typically used to prevent the loss of property or protect other community resources such as infrastructure and riparian areas. Localized projects are generally limited to the problem area, but should extend to stable locations to prevent future flanking or undermining. A series of local stabilization techniques may be employed within a larger reach-based stabilization plan, but by themselves they are intended to resist or divert the hydraulic forces causing erosion. In many cases the toe of a bank (foundation of bank slope) or other high shear stress areas in the channel require some “hard” reinforcement for a portion of the project. Upper banks can often be stabilized with “soft” reinforcements such as vegetation or reinforced earth. The goal for local stabilization is to establish a long-term solution for erosion control such that future rehabilitation is not necessary. Any stabilization scheme must include planning for future changes in channel geometry due to continued scour and channel instability in the project area. Where stormflows are projected to increase substantially in the future, local stabilization should be combined with detention and other stormwater management techniques at the watershed level. See Table 9.2.2-2 for an inventory of channel erosion control solutions and techniques.

Table 9.2.2-2 Inventory of Local Stabilization Techniques

Inventory of Local Stabilization Techniques	
Reinforced Earth	Rock Toe Treatments
Vegetative Bioengineering	Outlet Protection at Storm Drain Outfalls
Vegetation Reinforcement	Flow Deflection
Placed Rock Riprap	

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Reinforced Earth

Reinforced earth can provide effective erosion control of creek banks while supporting a vegetated surface treatment. Figure 9.2.2-1 shows a project using reinforced earthbank. Alternating soil lifts with reinforcing layers of geotextile fabric provides slope stabilization. This approach is often employed in areas with limited space because they can be structurally stable at slopes as steep as 0.5:1. Reinforced earth applications include: (1) narrow, deep channels (confined channel systems), (2) parkland, (3) protection of structures and roadways along the channel, (4) high velocity and high shear stress streams, and (5) severe channel bends.

Figure 9.2.2-1 Reinforced earth bank at Pecan Springs, Fort Branch watershed.

Vegetative Bioengineering

Bioengineering uses vegetative plantings introduced into soil backfill and slopes to provide erosion resistance, strength, and support from the plant root network. Typical plantings include dormant tree stakes or shoots or brush placed horizontally into banks. Plants are selected for extensive root systems, resiliency to flows and inundation, and capacity of self-support and self-repair. Plant survival is crucial to the usefulness of this technology. Figure 9.2.2-2 presents a typical vegetative bioengineering project.

Figure 9.2.2-2 Vegetative bioengineering along Blunn Creek at Big Stacy Park

Vegetative Reinforcement

Vegetation reinforcement refers to the integration of slope vegetation with materials such as rock riprap, flexible channel liners or fiber rolls, or other similar materials. Long-term stability of these measures along stream courses depends on establishing a dense, self-perpetuating plant community. Vegetation reinforcement techniques provide protection and support to the vegetative cover both during initial establishment and during periods of high erosive flows and channel shear stress.

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Placed Rock Riprap

Figure 9.2.2-3 Placed rock riprap on Tannehill Branch Creek at Lovell Drive

Rock riprap refers to loose, unconsolidated rocks that are placed along eroding side slopes. Placed rock riprap can be used in extended segments or in isolated trouble spots. Although more labor-intensive, mechanically-placed riprap provides much better protection than dumped riprap. Rock sizes and gradations must be designed considering the hydraulic forces of the stream, and high shear stress areas can require rocks 18-inches in diameter or larger. Riprap performs well in conjunction with vegetative slope protection techniques. When used to stabilize the toe of a slope, the rock must be sized so that its weight can resist applicable shear forces. Rock riprap can be augmented with vegetation using soil/rock mixtures and joint plantings between the voids in the rock. Typical application areas include: (1) severe channel bends, (2) near structures and roadways, and (3) transitions into and out of culverts, bridges, and channel improvements. Figure 9.2.2-3 shows local placed rock riprap projects.

Big Rock Toe Treatments

Figure 9.2.2-4 Big rock toe treatment in Williamson Creek tributary at Turnstone Drive.

Similar to rock riprap, “Big Rock” toe treatments offer erosion protection to the particularly vulnerable “toe” or foundation of a slope in the stream cross-section. Localized scour typically occurs at the toe of slope on outside of a channel bend, in the area downstream of a stormwater outlet, at bridge piers, and along wastewater lines. This toe treatment is often used in conjunction with other stabilization and revetment methods. In streams with frequent high shear stress flows and high velocities, the rock toe is extended below to the active channel to potential scour depth to maximize erosion prevention. Figure 9.2.2-4 depicts typical big rock toe treatments.

Outlet Protection at Storm Drain Outfalls

Outflow from storm drains and culverts often creates localized scour due to high flow velocities. High velocities occur when outfall pipes are steep or pipe flow is pressurized. The following list describes measures for reducing outlet scour:

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- Baffles - an array of concrete blocks that slow outlet flows by creating turbulence.
- Flattening the Outfall Pipe Slope - Steeper pipe slopes result in higher flow velocities. Flattening the outfall section pipe slope will slow the flow velocity before the flow leaves the pipe and prevent additional scour.
- Roughening the Outlet Section - Forming slats, impact beams, or small baffles within the outfall pipe creates roughness within the pipe that slows the velocity at the outlet.
- Extended Outfall Apron - An extended section of the outfall provides protection to the streambed where the outfall flow transitions to stream flow. The use of rock riprap around the edges prevents undermining and creates a roughened surface to minimize channel erosion.

Figure 9.2.2-5 shows typical outlet protection methods.

Figure 9.2.2-5 Outlet protection at storm drain outfalls: within pipe impact beam energy dissipater (left); outfall along Shoal Creek at 29th Street using rock riprap protection.

Flow Deflectors

Flow deflectors provide bank protection by directing channel flows away from the bank and promoting sediment deposition between the structures. Flow deflectors are constructed by placing boulders, rock riprap, gabions, or other materials in a linear alignment angled to the banks along a channel segment. Sediment deposits behind the deflectors can generate vegetation growth and promote additional stability. Location of channel deflectors on the outside of a channel bend is generally intended to keep the deepest portion of the channel toward the middle of the channel, reducing high, erosive velocities on the outside bank. Some common types of flow deflectors include spurs, dikes, bendway weirs, vanes, and jetties.

9.2.2.3 Reach-Based Stream Restoration

Reach-based stream restoration refers to the engineered modification of stream reaches to achieve long-term stability of the channel plan, profile, and dimensions while maintaining a natural channel bed form and stream banks. Reach-based restoration is a holistic approach to develop a stable, low-maintenance, and ecologically diverse riparian corridor within the context of the watershed. These goals are achieved by configuring a frequent flow channel complete with riffles and pools that will maintain itself. These solutions seek to address systematic problems in the stream network that result in large-scale channel erosion. They consider the interaction of adjacent channel sections in the design of solutions to channel erosion problems. This reflects a broader scope of rehabilitation in contrast to stand-alone localized stabilization techniques, which by themselves may not consider the stream system as a whole. Reach-based methods can have a favorable impact on restoring creek system integrity, overbank storage, and water quality. Reach-based solutions may incorporate some of the techniques discussed under Localized Stabilization Techniques, but may also include floodplain modification. Table 9.2.2-3 presents descriptions of techniques commonly employed by reach-based stream restoration:

Table 9.2.2-3 Reach-Based Stream Restoration Techniques

Reach-Based Stream Restoration Techniques	
Multi-Phase Channel Terracing	Grade Control
Re-meandering	

Multi-Phase Channel Terracing

Terracing or multi-stage channel design relieves channel stress by creating a connection of an incised channel to an inset floodplain bench or series of flood surfaces through excavation of the area adjacent to the impacted channel. Terraces allow the lowest channel to carry flows associated with the bankfull storm event, and the inset benches provide relief for larger storms. Figure 9.2.2-6 depicts terracing.

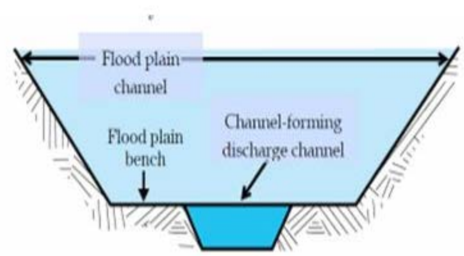
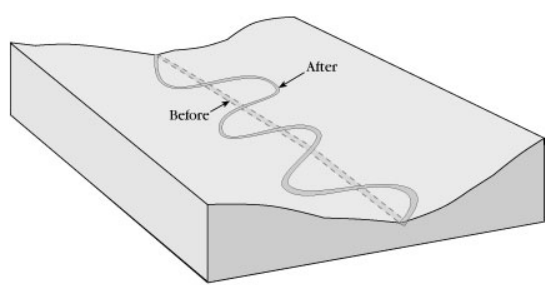


Figure 9.2.2-6 Schematic of terracing

Re-meandering

Re-meandering refers to restoration of the natural meandering channel flow path to increase stream length and reduce channel slope. This technology is typically employed as a restoration measure for streams that have been straightened and armored. The resulting flow has lower stream energy and therefore lower



Source: NRCS, 2001

Figure 9.2.2-7 Stream meander restoration erosion potential. Typically, the restored channel provides less conveyance than the "improved" channel, with increased floodplain conveyance compensating for the reduction in channel conveyance. Figure 9.2.2-7 illustrates stream meander restoration methods.

Grade Control

When watershed conditions create a channel degradation problem, the channel bed tends to downcut until non-erodible material is exposed. Where the limiting substrate is deep below the original natural creek bed, it may be advisable to arrest further channel downcutting through implementation of grade control.

Figure 9.2.2-8 Rock grade control structures

Figure 9.2.2-8 shows grade control structures, and Figure 9.2.2-9 shows grade control systems schematics. Types of grade control include rigid drop structures, rock drops, step-pools, constructed riffles, cross vanes, log structures, wing deflectors, and check dams. Historically, traditional drop structures may have been constructed out of concrete, but rock structures such as constructed riffles tend to be more flexible and less susceptible to catastrophic failure in the stream environment. Rock structures also provide for better aquatic habitat than concrete. The constructed riffle and step-pool design approach

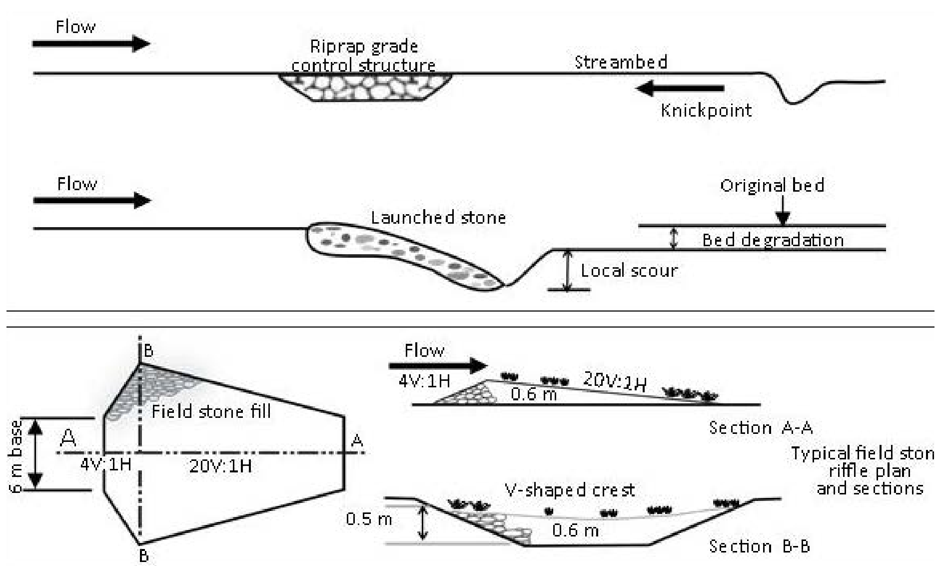


Figure 9.2.2-9 Grade Control System schematics

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involves the use of large rocks placed above and/or beneath the channel flowline to form a barrier to downcutting. They are designed for grade control to prevent head cuts from migrating upstream. Scour holes may form, but they must be keyed-in at the top, bottom, and along the side slopes to prevent undercutting and widening of the channel. Grade control may be used as a localized stabilization technique, but is often a component of a larger reach-based stabilization plan.

9.2.2.4 Stormwater Detention for Erosion Control

Stormwater detention offers a means of regulating peak flow rates to promote channel stability for urbanizing watersheds with significant expected future erosion and enlargement of the channel cross-section. Stormwater detention is generally designed to mimic the pre-development frequency of channel-forming runoff events (those frequent, short duration storm events that cause most of the bank erosion) by temporarily storing the storm runoff volume and regulating discharge flow rates. Outlets must be sized for release rates that consider downstream shear stress thresholds to avoid channel instability. Stormwater runoff detention is effective in preventing future erosion problems, but is not generally useful for remediation of current active erosion. Runoff detention for erosion control generally requires capture and control of storms that occur on a regular basis depending upon downstream channel conditions (i.e. rock-controlled vs. alluvial). Consequently, substantial land area for on-line or off-line runoff storage is necessary for this approach. Current regulations requiring new developments and redevelopment to provide extended detention for water quality preservation also significantly reduce erosion potential.

9.2.3 Water Quality Protection Capital Projects

Water Quality Protection capital projects are intended to limit the impact of non-point source (NPS) pollution on receiving waters. NPS pollution originates from diffuse, usually urbanized, runoff sources. Pollutants typically occur in relatively low concentrations; however, due to the large number of non-point sources, they usually constitute a significant portion of the overall pollutant load delivered to receiving waters. There are six groups of water quality control capital project solutions summarized in Table 9.2.3-1 below.

Table 9.2.3-1 Inventory of Water Quality Protection Capital Controls

Inventory of Water Quality Capital Controls	
Source Controls	Property Acquisition
Design Practices	Rangeland Management
Stormwater Treatment Measures	Riparian Restoration

All of the solutions focus on reduction of pollutant loads to receiving streams. Property acquisition and rangeland management strategies were originally considered under capital project solutions,

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but were referred to programmatic solutions as they lend themselves better to implementation through one of the City WPD operating programs, discussed in Section 9.3.

9.2.3.1 Source Controls

Source controls are those which attempt to limit the pollutant load contribution near the point of generation. For example, water quality inlets capture trash, debris, and coarse sediment within a few hundred feet of their original location in the watershed. These are successfully used in the 6th Street area of downtown Austin. These are maintenance intensive, and it is recommended to limit the use of these to areas where there will be a high return of avoided pollution, such as an intensely developed urban area, to offset the high demand for frequent maintenance. There are five identified source controls for water quality as shown in Table 9.2.3-2.

Table 9.2.3-2 Inventory of Water Quality Source Controls

Inventory of Water Quality Source Controls	
Secondary Containment	Good Housekeeping
Porous Pavement	Oil/Grit Separators
Integrated Pest Management (IPM)	

Secondary Containment

Secondary containment entails surrounding your storage containers with a barrier to protect the environmental from spills/leaks from bulk vessels. The type and size of the secondary containment needed varies according to the volume of hazardous substance held and the size of the containers. Title 40, Chapter 1, Section 267.195 and 6 of the Federal Register provides additional information and guidelines on requirements.

Secondary containment can be concrete walls large enough to contain the total volume of liquids stored within them, or as simple as low nib walls which stop spills from indoor workspaces escaping into yards. All pumps, pipes, valves, flanges, and decanting vessels should be within the secondary containment to catch any leaks, spills, or overflows. All loading points should be inside the secondary containment. Containment should be roofed, or have procedures for emptying rainwater without causing pollution. Floors, walls, and pipework of the containment should be impervious to the materials stored.

Porous Pavement

Porous pavement describes a variety of alternative techniques used to construct sidewalks, driveways, low volume parking lots, and other hard surfaces. Unlike conventional impervious pavement, porous

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pavement contains voids that encourage infiltration. Water stored in the underlying structure or sub-base infiltrates into the underlying permeable subgrade to reduce pollutants and provide groundwater recharge. Properly designed and installed, this pavement has load bearing strength and longevity similar to conventional pavement. Many different porous pavement systems are available, ranging from concrete to asphalt to grid pavers. Figure 9.2.3-1 shows a schematic of porous pavement and a sidewalk constructed of porous pavement. Highly detailed specifications, as well as ensuring experienced contractors complete the installation, is essential to minimize potential problems such as compaction of the subgrade or clogging with sediment.

Figure 9.2.3-1 Porous pavement: schematic (left); porous sidewalk in Slaughter Creek watershed (right).

Good Housekeeping Practices

Good housekeeping prevents pollution, staff accidents, and reduces environmental liability. Poor housekeeping practices are the most common cause of industrial pollution, and are easily avoided by established better work practices. Clean, well-managed sites are far less likely to cause pollution than untidy sites. The following are some examples of good housekeeping practices:

- Spill Kits
- Inspection Practices
- Proper Training of Staff
- Proper Waste Receptacles
- Spill Plans
- Contingency Plan and Maintenance

Oil/Grit Separators

Oil/grit separators (OGS) are typically two- or three-chambered underground retention systems that remove pollutants from roadways and parking lots. The first chamber is used for gravity settling of heavy particulates, adsorbed hydrocarbons, and heavy metals. The second chamber provides

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separation by flotation of fresh oil and other emulsified petroleum products. A third chamber usually provides additional storage volume, sediment settling capacity, and houses the storm drain outlet pipe.

Figure 9.2.3-2 presents a schematic representation of a three-chamber oil/grit separator. The use of OGS systems is usually restricted to small, highly impervious basins of about two acres or less, and is particularly appropriate for sites expected to receive high amounts of vehicular traffic or petroleum inputs, such as gas stations, roads, and loading areas. They can also be used as pre-treatment for wet storage facilities to prevent visible oil on the surface of the permanent pool.

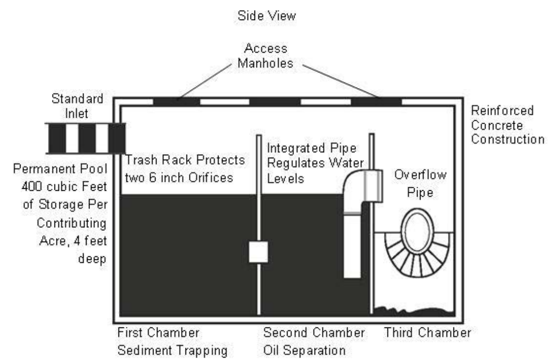

Figure 9.2.3-2 Oil/Grit Separator

Integrated Pest Management Plans (IPM)

Integrated pest management (IPM) is an environmentally-sound method of managing pest and landscape maintenance practices. Landscapes are monitored regularly, problems properly identified, severity considered, control options evaluated and selected, and then least toxic controls are implemented. Main IPM messages include:

- Accurately diagnosing problems before considering any treatment
- Use least toxic solutions
- Don’t apply fertilizes or pesticides before a rain
- Don’t kill every bug – 95% of insects aren’t pests
- Use pesticides as a last resort
- Always read and follow pesticide label instructions
- Encourage beneficial insects

Choice of control option(s) is based on effectiveness, environmental impact, site characteristics, worker/public health and safety, and economics. IPM takes advantage of all appropriate pest management options.

9.2.3.2 Design Practices

Design practices help integrate environmental management techniques as part of the product and service by either helping to eliminate the problem before it occurs or by reducing or preventing problem reoccurrence. Table 9.2.3-3 shows design practice solutions.

Table 9.2.3-3 Inventory of Design Practices

Inventory of Design Practices	
Facilities Layout	Impervious Cover Removal
Retrofitting of Ponds for Trash Removal	Impervious Cover Disconnection

Facilities Layout

Design practices associated with location of facilities, such as moving potentially polluting activities inside under the protection of a roof, rather than locating the facility outdoors, can significantly reduce or eliminate many types of pollution. Incentive for this is provided in the implementation of federal law, through the issuance of a non-exposure certificate by the Environmental Protection Agency as part of compliance with the Clean Water Act.

Retrofitting of Existing Stormwater Management Ponds for Trash Removal (Trash Screens)

The use of trash screens in existing water quality ponds is generally applied as an added non-point source control feature, used in conjunction with the primary water quality or flood mitigation purposes of the ponds. Retrofitting an existing stormwater management pond usually involves placing a screening device at the outflow structure to assure that trash and debris is captured and stored in the pond. It is important to assure that trash accumulation does not impact the intended flow characteristics of the outflow structure, or impair the original function of the facility.

Impervious Cover Removal

Impervious cover removal involves removing impervious surfaces and replacing them with stabilized, vegetated pervious cover. The new pervious surface reduces runoff and increases infiltration. This approach can be used where impervious cover is over-built for its intended purpose, or has become obsolete through site abandonment. Application of this approach would best be implemented as a citywide program because, prior to capital implementation, this approach will require significant investigation of practical applicability, land ownership constraints, and cost/benefit issues. Example applications include removing parking lot pavement, replacing it either with pervious pavements or pervious landscaped areas (see discussion of “Porous Pavement” in Section 9.2.3.3 below).

Impervious Cover Disconnection

Disconnection of impervious cover is a retrofit technique involving removal of the direct path of stormwater flow between impervious cover and waterways. This practice operates on the principle that the negative impacts of impervious cover on water quality and quantity can be reduced if runoff from these areas is redirected over pervious areas for possible storage, energy dissipation, and

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filtration-infiltration. Conventional site designs often encourage water to exit as rapidly as possible via impervious conveyance paths (storm drains, storm drains, concrete-lined channels, etc.). This technique calls for reconfiguring drainage structures to direct runoff from rooftops, roadways, and parking lots across landscaped or other pervious areas prior to discharging into waterways.

9.2.3.3 Stormwater Treatment Measures

Treatment controls are those that capture and remove pollutant loads generated by multiple sources. They are typically located on-line or off-line along creeks and tributaries and involve capture of at least the first half-inch to inch of stormwater runoff (often called the first flush). Stormwater treatment measures may be placed individually, or in series with similar or different control technologies. They are most effective when they are able to treat multiple pollutant types and be multi-purpose in operation. For example, a wet pond can incorporate baseflow storage and provide erosion control volume while addressing multiple pollutant types. Table 9.2.3-4 shows stormwater treatment measures.

Table 9.2.3-4 Inventory of Stormwater Treatment Measures

Inventory of Stormwater Treatment Measures	
Retention-Irrigation Systems	Vegetative Filter Strips - Disconnection of Impervious Cover
Wet Ponds	Non-Required Vegetation
Constructed Stormwater Wetlands	Biofiltration
Sedimentation/Sand Filtration	Rain Gardens
Extended Detention	Water Quality Inlets
Grassed Swales	Inlet Absorbents
Rainwater Harvesting	Trash and Debris Booms
Vegetative Filter Strips	Hazardous Materials Traps

Retention-Irrigation

Retention-irrigation refers to the capture of stormwater runoff in a holding pond, and the subsequent use of the captured volume for irrigating landscape or natural pervious areas. This technology is highly effective as a water quality control and results in very high stormwater pollutant removal efficiencies. This technology mimics natural undeveloped watershed conditions. A retention-irrigation water quality treatment system consists of two primary components: (1) a basin which captures and isolates the required volume of stormwater runoff, and (2) a distribution and land application system which generally utilizes pumps, piping, and spray irrigation components. When properly designed, this system is effective in removal of pollutants through settling in the retention basin and contact with vegetation, air, and soils in the irrigation process. It also effectively mitigates stream-bank erosion.

Although water quality performance is excellent, maintenance requirements and construction costs for retention-irrigation systems are high. Land availability is also an issue. This approach is most often applied in sensitive watersheds as a means of achieving stormwater non-degradation. Figure 9.2.3-3 presents a schematic design for a typical retention-irrigation system.

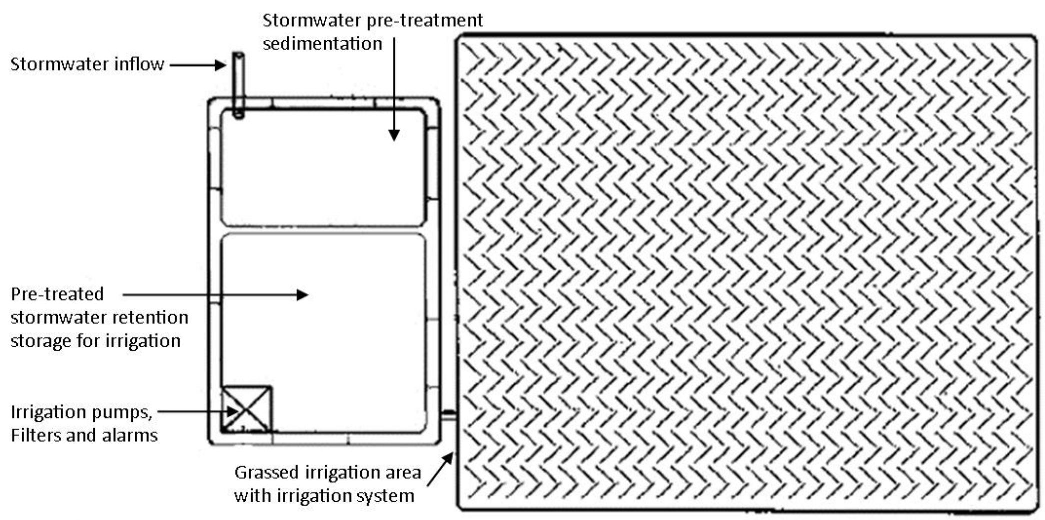

Figure 9.2.3-3 Retention-irrigation system schematic

Wet Ponds

Wet ponds maintain a permanent wet pool to detain and treat stormwater runoff. This technology provides stormwater quality enhancement for a wide range of pollutants. Wet ponds are designed to encourage the maintenance of healthy emergent and submerged aquatic vegetation, and an active microbial community capable of dissolved pollutant breakdown.

If properly designed and sized, sedimentation processes can capture a significant amount of the particulate fraction. Permanent wet storage may serve as a stand-alone treatment, or may be used in conjunction with other measures such as erosion control, flood mitigation, or baseflow.

Additional benefits include creation of aquatic, wetland, and terrestrial habitat, and high community acceptance for aesthetic value. Wet ponds may be constructed on- or off-line and can be sited at feasible locations along established drainage patterns. They are best suited to small subwatersheds with residential land uses or other uses where high nutrient loads are expected (such as golf courses). Although wet ponds can provide water quality treatment and wildlife habitat, they are potentially very water intensive due to the need to maintain a permanent pool water level. Figure 9.2.3-4 presents two wet pond systems.

Figure 9.2.3-4 Wet ponds: St. Elmo, in Willamson Creek watershed (left); Central Market pond, Waller Creek watershed (right).

Constructed Stormwater Wetlands

Constructed stormwater wetlands are shallow, vegetated ponds that are engineered and constructed to mimic the structure, water quality function, wildlife habitat, and aesthetic value of naturally occurring wetlands. Figure 9.2.3-5 presents a schematic diagram of a typical constructed wetland solution.

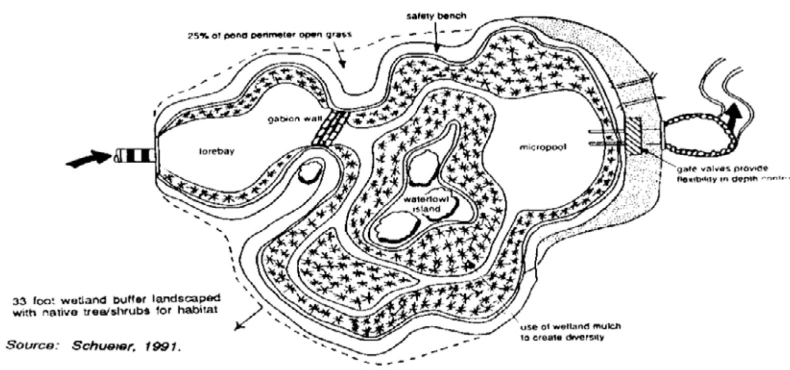

Figure 9.2.3-5 Constructed Wetland

Constructed wetlands generally feature uniformly vegetated areas with depths of one foot or less, and open water areas as deep as four feet. Wetland vegetation is made up of native aquatic plant species. Constructed wetlands can be designed on-line or off-line and usually serve smaller drainage areas than wet ponds. Constructed stormwater wetlands need sufficient baseflow, groundwater, and/or contributing drainage area to maintain year-round wet conditions for survival of aquatic vegetation.

Natural wetlands can be modified to handle additional inflows of pollutant loads and water volumes from new developments. In the Austin area, such modification is usually limited to old stock ponds that have developed over time as wetlands. At this time, constructed wetlands are not included as a water quality control option in the City of Austin's Environmental Criteria Manual.

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Sedimentation-Sand Filtration

Sedimentation-filtration ponds are stormwater capture structures that provide two-stage treatment of stormwater. Two designs, full and partial sedimentation, are allowed by the Environmental Criteria Manual. The full sedimentation basin detains the first flush runoff, generally at least the first half-inch with a minimum draw-down time of about 24 hours. The partial sedimentation system stores the captured water in both the sedimentation and filtration portions of the facility, but requires a larger filter area. Effluent is discharged to the filtration basin, which includes a sand filter, a geotextile layer, and gravel. A perforated PVC piping system drains filtered flows from the filtration basin. Pollutant removal is primarily through physical filtration.

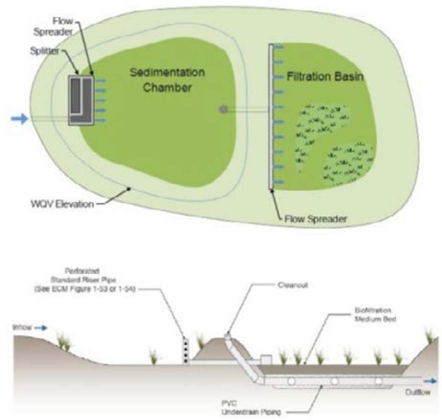

Figure 9.2.3-6 Sedimentation-filtration schematic.

Sedimentation-filtration ponds are built as on-line or off-line systems, and are typically used to treat runoff from small, newly developed sub-watersheds. Off-line sedimentation-sand filtration can achieve high levels of average annual load removal for suspended solids and associated toxic load. Figure 9.2.3-6 presents a schematic of a sedimentation-filtration system as typically implemented in Austin.

Extended Detention

Extended detention (ED) refers to the capture and slow release of stormwater runoff. ED facilities can be on- or off-line. Off-line ED facilities are typically designed to remain dry between runoff events. However, like wet ponds, this approach can be used to target multiple stormwater missions, including water quality, erosion control, baseflow enhancement, and flood mitigation for higher frequency events. ED ponds can be designed in conjunction with other structural stormwater practices such as wet ponds, or as stand-alone facilities. Extended detention technologies require sufficient open land with a grade that allows for placement of a stormwater storage facility. Depending on detention time, ED ponds used alone generally provide moderate to high (although variable) particulate pollutant removal, but poor removal for dissolved constituents. Figure 9.2.3-7 presents an extended detention system.

Figure 9.2.3-7 Extended detention basin on St. Edward's University Campus

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Grassed Swales

Grassed swales are vegetated and graded open channel systems that are designed to convey runoff as low velocity, overland flow. They require dense vegetative cover. As an alternative to curb and gutter systems, swales are designed to convey runoff while promoting infiltration, settling, and capture of particulates. Performance is directly proportional to contact time; thus longer swales with slower velocities provide greater water quality enhancement. They can also be used as a passive solution for site development drainage and as an alternative to curb and gutter storm drain systems. Performance can be severely compromised if slopes are excessive or if erosion along the swale concentrates flows. At this time, grassed swales are not included as a water quality control option in the City of Austin's Environmental Criteria Manual. Figure 9.2.3-8 presents a typical grassed swale schematic.

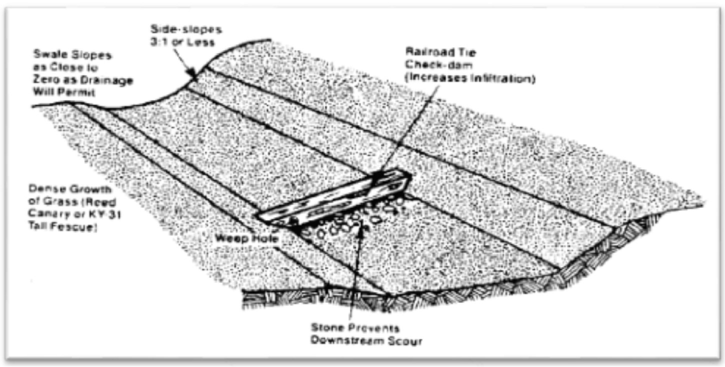

Figure 9.2.3-8 Typical grassed swale

Rainwater Harvesting

Figure 9.2.3-9 Rainwater harvesting at single-family residential site in Shoal Creek watershed

Rainwater harvesting systems divert stormwater runoff from building roofs into a holding tank or cistern via gutters and pipes. Figure 9.2.3-9 shows a home with a rainwater harvesting tank. Stored water is irrigated during dry weather onto landscapes or other pervious surfaces such that little or no runoff occurs. This technology reduces peak runoff flows, enhances vegetative growth, and promotes infiltration. Rainwater systems usually take runoff exclusively from rooftops. This water is relatively clean compared with road or fertilized turf runoff. The high quality of the captured water makes rainwater harvesting suitable for water reuse and consumption. Rainwater harvesting systems are widely applicable for residential or commercial properties where there is sufficient pervious area for irrigation, or sufficient potable water need. Rainwater harvesting systems can be relatively simple to install on existing structures, and require only a small area for the tank and pump house.

Vegetative Filter Strips

Vegetative filter strips (VFS) are typically used in areas with relatively low-density development as a passive, low-maintenance means of protecting nearby receiving waters from marginally increased pollutant loads. Figure 9.2.3-10 presents a typical vegetative filter strip.

They are designed to treat uncontrolled runoff. The use of existing vegetative filters should be limited to gently sloping areas where shallow flow characteristics are possible. Filter strips provide water quality enhancement through infiltration, settling and capture of particulates, biological uptake processes, and physical filtration. They mimic natural watershed conditions by promoting localized runoff storage and infiltration. For filter strips to work effectively, sheet flow must be maintained and maximum velocities in the filter strip must not be exceeded. This requirement will limit the size and/or impervious cover to what is practical for treatment. The VFS shall be restricted from development or any use that may negatively affect the function of the VFS (e.g., intensive recreational uses, pet use, etc.). An approved Integrated Pest Management Plan with a recorded restrictive covenant should be required. It is extremely important that the VFS not be over-irrigated and that fertilizer and chemical use be minimized; otherwise the VFS may become a source of pollution instead of a treatment best management practice (BMP).

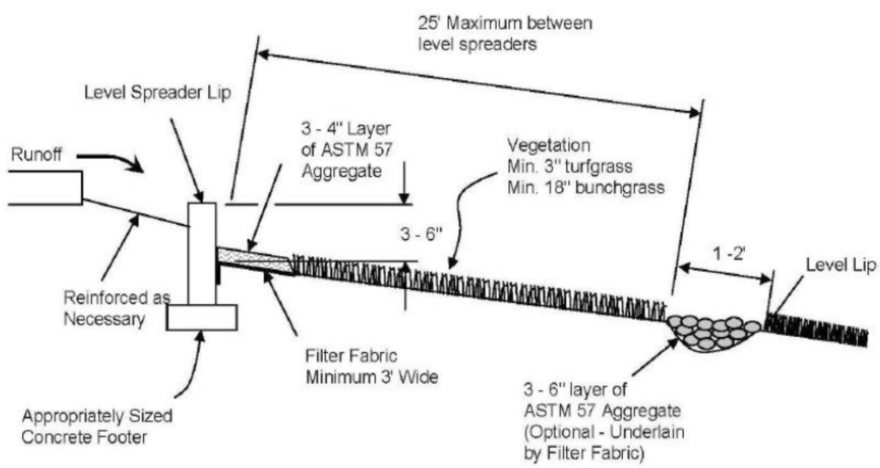

Figure 9.2.3-10 Vegetative filter strip schematic

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Vegetative Filter Strip – Disconnection of Impervious Cover

The disconnection of impervious cover and treatment of stormwater runoff by vegetative filter strips are considered a water quality control BMP. This system uses the physical filtration properties of plants and infiltration properties of soils for removal of pollutants from stormwater runoff. Vegetative filter strips for treatment of disconnected impervious cover can provide partial treatment equivalent to a standard sedimentation-filtration system. Figure 9.2.3-11 shows a parking lot with at-grade landscaping that allows stormwater to infiltrate rather than runoff to a storm drain.

Figure 9.2.3-11 At-grade landscaping allows stormwater to infiltrate, providing water quality functions

Non-Required Vegetation

Additional non-required vegetation, especially trees, can help reduce stormwater runoff and enhance groundwater recharge by breaking the impact of raindrops and improving soil structure. A tree's effectiveness in this capacity is correlated with the size of the crown and root zone area. There are numerous environmental and stormwater benefits to additional vegetation. Non-required vegetation can act as natural stormwater management area by filtering particulate matter, including pollutants, some nutrients, sediments, and pesticides, and by absorbing water. A study done by the U.S. Department of Agriculture's Center for Urban Forest Research found that a medium-sized tree can intercept 2,380 gallons of rain per year (Center for Urban Forest Research, 2002).

Biofiltration

Biofiltration ponds are water quality control best management practices (BMP) that use the chemical, biological, and physical properties of plants, microbes, and soils for the removal of pollutants from stormwater runoff. Biofiltration is a critical component of Low Impact Development (LID). LID is a philosophy of development in which steps are taken to maintain pre-development hydrology, as near as possible. Green space is made functional to keep stormwater on-site, minimize runoff, and employ natural processes for water quality improvement.

A biofiltration system utilizes several treatment mechanisms for removing pollutants from stormwater runoff. As with a sand filtration system, a sedimentation basin provides pre-treatment of runoff in order to protect the biofiltration media from becoming clogged prematurely by sediment loads. Likewise, sand filtration and biofiltration both remove pollutants through physical filtration.

A primary difference between the two is that the presence of a biological community of plants and microorganism in a biofiltration system can theoretically provide more treatment of runoff. Another benefit of having a plant community is that the permeability of the biofiltration media may be sustained for longer periods of time without maintenance.

In general, the biofiltration basin should be planted with native or adapted grasses and forbs. Small trees (< 8" diameter at maturity) can be incorporated around the perimeter, above the water quality volume, as long as the underdrain system is protected from penetration by the tree root system. Figure 9.2.3-12 shows a biofiltration pond in the downtown area, along Lady Bird Lake.

Figure 9.2.3-12 Biofiltration pond near Lady Bird Lake

Rain Gardens

A rain garden is a filtration and/or infiltration system that has a contributing drainage area that does not exceed one acre, and a ponding depth not to exceed 12 inches. Unlike conventional centralized stormwater management systems, the rain garden approach may employ multiple controls dispersed across a development and incorporated into the landscape, providing aesthetic as well as ecological benefits. As with sand and biofiltration systems, a rain garden will provide physical filtration of pollutants in stormwater runoff. However, because of the small drainage area and shallow ponding depth, which necessitate a larger surface area, biological and plant uptake mechanisms may be more significant for rain gardens. Figure 9.2.3-13 shows a typical rain garden.

Potential problems can occur if rain gardens are over-irrigated and receive significant applications of fertilizers and herbicides, as they can become sources of pollution rather than pollutant removal BMPs. It is essential that these rain garden systems be managed carefully, and that an approved and recorded Integrated Pest Management plan be required for the drainage area up to and including the rain garden.

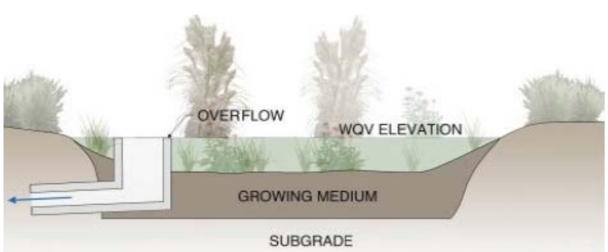

Figure 9.2.3-13 Schematic for a full infiltration rain garden (above) and a rain garden along Blunn Creek in Stacy Park (right).

Water Quality Inlets

Stormwater inlet filters are fabricated from tubular steel and perforated aluminum, which are inserted inside storm drain inlets to trap trash and other debris. The filter can easily be removed through the curb opening for service, and then re-installed for the next storm event. Monitoring has indicated that some sediment and other pollutants are collected on the screen portion of the filter. Inlet filters are typically retrofit into existing storm drain inlets. Inlet filters are generally not as useful in single-family residential areas due to the lower concentrations of trash and litter, except in areas with high pedestrian activity or near businesses such as convenience stores. Figure 9.2.3-14 illustrates the inlet filter design used by the City of Austin.

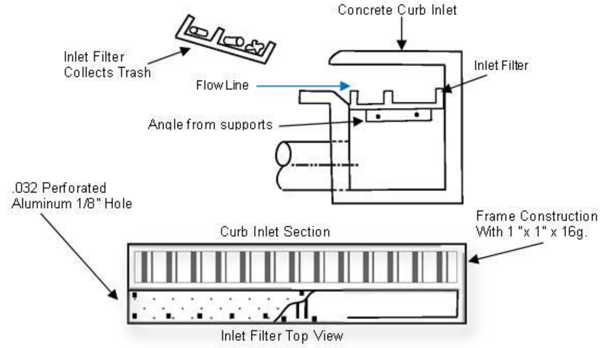

Figure 9.2.3-14 Water quality inlet filter

Inlet Adsorbents

Inlet adsorbents are a retrofit technique to place adsorbent filters, pillows, sheets, or socks in stormwater inlets to remove oil and grease from stormwater before it enters the storm drain system. Because the petroleum hydrocarbon component is virtually impossible to remove through settling, inlet adsorbent materials are one of few effective techniques. Inlet adsorbents can be installed in conventional stormwater inlets and are a logical companion to inlet filters.

Trash and Debris Booms

Trash and debris booms are modified oil spill containment booms placed across urban creeks (generally near the confluence with a downstream waterbody) to catch floatable trash and organic debris. Booms are secured so that they are not destroyed by the full force of high-velocity flows. By capturing floatable trash and woody-organic debris, booms target the most obvious, visual signs of non-point source pollution. Experience in Austin has shown that trash booms on urban creeks can catch more than 60 gallons of trash and debris per storm event. Booms must be maintained frequently to avoid aesthetic concerns, since booms accumulate floating debris in and on the surface of the receiving water. Figure 9.2.3-15 presents a trash and debris boom deployed in Shoal Creek.


Figure 9.2.3-15 Trash and debris boom

Hazardous Materials Traps

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Hazardous materials traps (HMTs) are retention basins designed to capture hazardous material spills along roadways. HMTs are sized to hold the contents of a standard tanker truck or rail car (approximately 8,000 gallons). To function as intended, HMTs must be empty at the time of a spill. Most are fitted with an inverted siphon to drain captured stormwater. Figure 9.2.3-16 presents a schematic of a typical hazardous materials trap.

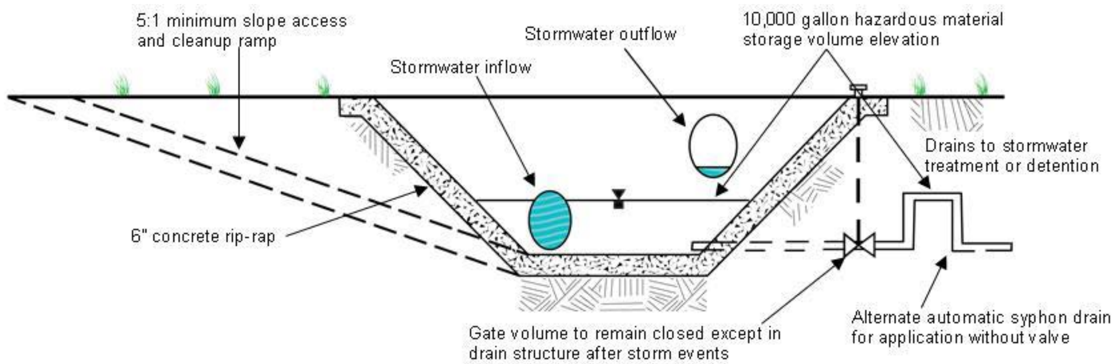

Figure 9.2.3-16 Hazardous materials trap schematic

9.2.3.4 Property Acquisition for Enhancement of Water Quality Control

There are two property acquisition options that can be used for water quality control purposes. Table 9.2.3-5 outlines those four techniques.

Table 9.2.3-5 Property Acquisition Techniques

Property Acquisition Techniques	
Land Acquisition	Conservation Easements

Land Acquisition

Land acquisition for water quality protection involves the purchase of strategically sensitive lands and protecting raw lands from being developed to maintain low, pre-developed pollutant loads in perpetuity. Purchases are made from willing sellers. Land to be considered for acquisition should have several characteristics: (1) relatively high degree of long-term development pressure, (2) high environmental value (inherent value or value as a prospective site for future

Figure 9.2.3-17 Permanently protected land on the Avana tract in the hill country of southwest Austin

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water quality controls), and (3) an owner who is willing to sell. Acquired lands may provide other indirect benefits such as endangered species protection or preservation of baseflow and aquifer recharge. Figure 9.2.3-17 shows land purchased to protect water quality.

Conservation Easements

Conservation easements for water quality protection are legal agreements with property owners to limit development of properties covered by the easements. Development restrictions can range from partial to total purchase of development rights. Conservation easements differ from land acquisition in that the property owner maintains legal possession of the land, while the easement holder acquires the raw land development value. This option is most feasible for undeveloped land, but may be applicable in some situations on land with low-density development.

9.2.3.5 Rangeland Management Strategies

Ranchers have traditionally used rangelands in Central Texas for grazing cattle, goats, and sheep. Rangelands represent the predominant land use in Austin's outlying watersheds to the west. Due to their large contributing drainage area, the condition of these lands may have a significant effect on water quantity and quality. Poor management practices have left much of this area in a deteriorated condition. Recent research shows that improved management of rangelands can stabilize soils, restore vegetation, increase rainfall infiltration, augment creek baseflows, and reduce sedimentation and nutrient export. Table 9.2.3-6 presents three rangeland management strategies.

Table 9.2.3-6 Rangeland Management Strategies

Rangeland Management Strategies	
Native Grass Establishment	Control of Livestock in Riparian Areas
Specialized Grazing Systems	

Native Grassland Establishment

Grassland establishment involves clearing undesirable brush species (such as juniper and cedar) and planting native bunch grasses. The presence of undesirable brush species can result in substantial interception of rainfall, reduction in infiltration (and thus baseflow), and suppression of groundcover vegetation. Bunch grasses form a thick groundcover with an extensive root system, a combination that serves to impede overland flow, reduce sediment movement, and increase infiltration and resulting creek baseflow.

Not all rangelands are suitable for grassland establishment. Many areas with cedar are habitat for the endangered golden-cheeked warbler, which the Balcones Canyonlands Preserve seeks to protect. Juniper is a well-adapted native in the Texas Hill Country, and its historic place in steep, rugged

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canyons should be preserved. Removal of junipers from these areas could significantly increase erosion and sedimentation. Some flatter, more upland stands of cedar should also be left intact. The selection of areas for grassland establishment should be carefully determined on a site-by-site basis.

Control of Livestock in Riparian Areas

Riparian areas constitute critical buffer zones for creek protection. Overuse by livestock in these areas causes damage to the stream channel and to protective riparian vegetation. Cattle and other livestock prefer to remain in close proximity to waterways as they provide drinking water, shade, and locally cooler temperatures. Vulnerable areas along riparian areas should be protected from over-use by livestock with fencing, rotational grazing, and other methods. Control of livestock in riparian areas is widely applicable in ranch lands.

Use of Specialized Grazing Systems

Many experts contend that rangelands are best served by management systems that control the number and location of livestock on a given property. Traditionally, livestock herds have been maintained at low intensities on a given site for extended periods of time. In many cases, highly desirable grazing areas, such as riparian zones, are heavily used and are not permitted sufficient opportunity to recover. Management theories have been proposed indicating that rangelands are best used intensively for short periods with long periods of rest. These theories maintain that short grazing regimes mimic natural patterns of herd animal behavior, thereby stimulating native vegetative systems, which in turn protect soil and water resources. While specialized grazing systems are applicable throughout the ranch lands of Central Texas, given the trend toward subdivision of large ranches into smaller rural parcels, it may be necessary for ranchers and other landowners to work collaboratively.

9.2.3.6 Riparian Restoration

A result of an expanding and increasingly urbanized metropolitan area, the riparian vegetation communities of Austin-area streams continue to transform further from their natural state (Duncan et al., 2011). In addition to providing a range of water quality benefits to streams (Mayer et al., 2005; Meyer et al., 2007) including the reduction of bacteria concentrations through stormwater filtration, dilution, and reduction of suspended sediments (Casteel et al., 2005; Lee et al., 2003; Meals, 2001; Young et al., 1980), riparian systems provide a suite of ecosystem services including stabilized stream banks, diverse animal assemblages, and groundwater recharge (Richardson et al., 2007) (Figure 9.2.3-18).

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Through decades of urban development with limited protective setbacks from riparian areas and inappropriate maintenance practices, riparian buffers on public and private lands have been severely degraded throughout the entire region. In Austin increased urbanization, represented by the percent impervious cover within the watershed, is related to changes in hydrology, resulting in shifts in vegetation composition (Sung et al., 2011). Impervious cover within riparian zones has also been directly related to bacteria concentrations in streams (Porras et al., 2013).

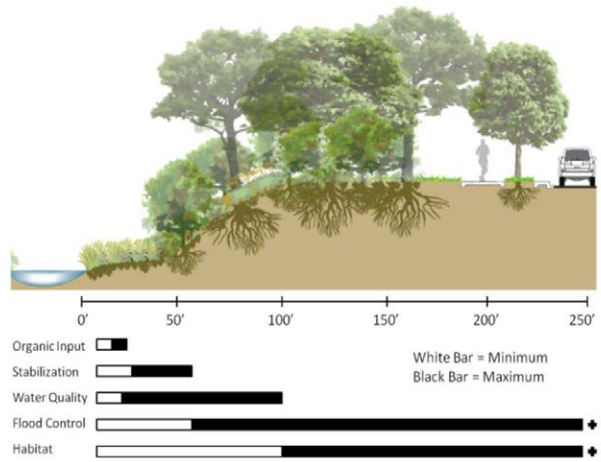

Figure 9.2.3-18 Ecological functions performed by riparian zones by width from wetted stream edge inland

The more degraded an ecosystem, the more fundamentally altered the basic services will become (Hobbs and Cramer, 2008). The reduction or elimination of activities causing the degradation or prevention of natural recovery may be all that is necessary to restore riparian function and improve water quality (Kauffman et al., 1997; Richardson et al., 2007), although more active restoration efforts may be necessary to restore ecological function when environmental disturbance is extreme (Hobbs and Prach, 2008).

Riparian restoration may be accomplished through capital improvement projects when more active slope modification, concrete removal, and large-scale vegetation management is needed to restore ecological function. Modification of mowing practices with a minimal amount of invasive species removal or native vegetation seeding is a highly effective passive approach that not only reduces land management maintenance burden, but also restores the ecological function of riparian zones over time (Figure 9.2.3-19).

Figure 9.2.3-19 Change in riparian zone condition when passive transition from mowed area occurs.

9.3 Operating Programs

Operating programs are implemented as City operating programs involving ongoing stormwater management activities with a long-term budgetary commitment. Examples of operating programs include infrastructure maintenance, emergency spills and complaints response, design review and inspection for new development, the Flood Early Warning System, and water quality monitoring.

The Inventory of Programmatic Solutions summarizes the existing City programs funded through WPD's annual operating budget, and administered by WPD. Programs are generally categorized by the three WPD missions: Flood Mitigation, Erosion Control, and Water Quality Protection. Some programs are considered to be integrated, i.e., they address all three program areas.

9.3.1 Existing Flood Mitigation Programs

Flood Mitigation programs focus on effective conveyance of stormwater flows and minimization of impact from flood-stage waters, and include programs shown in Table 9.3.1-1.

Table 9.3.1-1 Existing Flood Mitigation Operating Programs

Existing Flood Mitigation Operating Programs	
Creek Flood Hazard Mitigation	Local Flood Hazard Mitigation
Flood Early Warning System (FEWS)	Regional Stormwater Management
Floodplain Management	Stormwater Pond Safety
Flood Hazard Public Information/PIO Community Services	Vegetation and Land Management
Infrastructure Inspection	Open Waterways Maintenance
Waller Creek Tunnel Operations and Maintenance	Storm Drain Cleaning
Field Engineering Services	Storm Drain Rehabilitation

9.3.1.1 Creek Flood Hazard Mitigation

The purpose of Creek Flood Hazard Mitigation activity is to reduce creek flood hazard conditions in order to protect lives and property. Creek hazard mitigation projects are planned, designed, and constructed to reduce flood hazards for houses, commercial buildings, and roadway crossings due to out-of-bank creek overflows during extreme storm events. Project types include bridge and culvert upgrades, buyout of floodplain properties, stream channel

Figure 9.3.1-1 The Hoeke Ln. low-water crossing was upgraded in 2012.

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enlargement, and construction of regional detention basins and flood walls/levees. This program applies for and manages federal grants and a large U.S. Army Corps of Engineer project that focuses on the buyout of flood-prone properties. Figure 9.3.1-1 shows a low water crossing upgrade implemented through the Flood Hazard Mitigation program.

9.3.1.2 Flood Early Warning System (FEWS)

The Flood Early Warning System (FEWS) program gathers real time rainfall and stream-flow stage data. This information is analyzed by FEWS operators and is used to provide advance warning of potential flood conditions for emergency response personnel. The FEWS program was initiated in 1986 in response to the devastating 1981 flood on Shoal Creek. It has improved the City's emergency response capabilities with respect to road closings, evacuation of flood-prone areas, and public notification of hazardous conditions. The primary goal of this program is to enhance public safety. The FEWS program provides support to the Office of Emergency Management, provides hydrologic data collection and data monitoring, stream gauge monitoring, FEWS software and hardware maintenance, post-flood reconnaissance and damage documentation, FEWS operator training, and hydrologic and hydraulic data maintenance. Figure 9.3.1-2 shows flood gauges across Austin.

Figure 9.3.1-2 Flood gauges across the city enhance public safety by collecting real-time rainfall data.

9.3.1.3 Floodplain Management

The purpose of Floodplain Management activity is to protect lives and property from flood hazards. The program maintains hydrologic/hydraulic floodplain models and maps, provides floodplain information to the public, reviews and processes floodplain variance requests, reviews floodplain development proposals, and coordinates the City's participation in the National Flood Insurance Program and Community Rating System. Figures 9.3.1-3 and 9.3.1-4 depict floodplain maps for the Austin area.

Figure 9.3.1-3 Floodplain maps help the City and public prepare for flooding

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9.3.1.4 Flood Hazard Public Information/PIO Community Services

Flood hazard public education efforts are implemented in conjunction with the Flood Early Warning System and the departmental Public Information Office. This program provides floodplain status information and a basic understanding of flood threats and options for citizens living in regulatory floodplain areas. This program also promotes avoidance of dangerous behaviors (e.g., driving through overtopped low-water crossings) during extreme events.

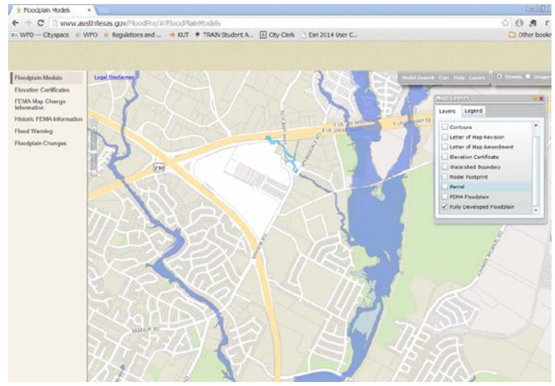

Figure 9.3.1-4 Floodplain information is available to the public at: www.austintexas.gov/FloodPro/

9.3.1.5 Enclosed Infrastructure Inspection Program

This program consists of two video inspection crews that run a closed circuit television camera within the drainage conduit system to evaluate and categorize the condition of assets. This program utilizes a nationally recognized asset management classification system, which is then used to prioritize problems and potential solutions or repair. Figure 9.3.1-5 shows the equipment used for TV inspection.

Figure 9.3.1-5 A pipeline inspection camera allows the crew to view the inside of a drainage pipeline

9.3.1.6 Waller Creek Tunnel Operations & Maintenance

The Waller Creek Tunnel Facilities Operations and Maintenance (O&M) program provides operations, maintenance, engineering, and related mission support to the Waller Creek tunnel system in order to provide flood control to protect lives and property. This includes the inlet facility at Waterloo Park, a mile long tunnel that ranges in diameter from 22 to 26 feet, two side-stream inlet facilities, and an outlet facility located at Lady Bird Lake. This program supports services to maintain regulatory code and design criteria for the anticipated redevelopment and revitalization of the Lower Waller Creek watershed. The activity also provides ongoing vegetation maintenance and removal of trash and debris along the Waller Creek District to provide for improved water quality and community use of the natural resources.

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9.3.1.7 Field Engineering Services

The purpose of Field Engineering Services activity is to provide drainage problem assessment services, utility location services, utility coordination services, assistance with drainage easement acquisition/release/licensing services, and small project construction design and management services to protect lives and property from flood hazards.

9.3.1.8 Local Flood Hazard Mitigation

The purpose of the Local Flood Hazard Mitigation (LFHM) program is to reduce local flooding conditions to protect lives and property. Improvement projects are planned, designed, and constructed to reduce local flood hazards for houses, commercial buildings, and roadways due to inadequate storm drain systems. Project types include curb inlets, area inlets, storm drain pipe networks, drainage ditch improvements, and small detention pond improvements. The improvements address 1) upgrade needs for older existing infrastructure and, 2) new drainage infrastructure for areas lacking local drainage management systems.

Citizens living in subdivisions developed prior to the publication of the Drainage Criteria Manual (DCM) are more vulnerable to local flooding due to undersized and aged storm drain systems. They communicate local flood concerns to LFHM through the 3-1-1 customer service request line. The LFHM has prioritized the concerns to date and has identified more than 50 capital improvement projects and several smaller projects. Figure 9.3.1-6 shows localized flooding in Williamson Creek watershed.

Figure 9.3.1-6 Road flooding due to inadequate storm system capacity. White spray reveals water backing up at an overloaded stormwater drain inlet.

The LFHM models hydrology and hydraulics for each area to determine the optimal solution to local flooding issues. The LFHM uses outside consultants for large projects, but designs smaller projects with City staff. The LFHM coordinates with other City departments and developers to ensure long term success of the City of Austin storm drain infrastructure.

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9.3.1.9 Regional Stormwater Management

This program provides an opportunity to participate in jointly-funded regional stormwater management facilities in lieu of providing on-site flood detention. The program manages the Regional Stormwater Management Program (RSMP) Fund used to plan, purchase property, design, and construct regional stormwater facilities, channel improvements, and culvert and storm drain upgrades for flood control. The program also provides preliminary engineering assessments for regional facilities, project planning and design, oversight and review of Master Plan hydrologic and hydraulic models, and drainage analysis for site developments.

9.3.1.10 Stormwater Pond Safety

The Stormwater Pond Safety program manages the risk of dam, floodwall, or levee failure by assuring that flood mitigation structures meet or exceed state safety criteria. This program assesses the modifications required to existing high hazard dams to comply with safety criteria, including the assessment of risk to downstream properties. The program also performs hydrologic/hydraulic planning and analysis, design and construction of structural improvements, and is responsible for the pond dam inventory database, dam and floodwall/levee structural inspection, emergency action plan preparation, and establishment of City criteria defining acceptable engineering procedures for design, construction, operation, and maintenance practices.

9.3.1.11 Vegetation and Land Management

The purpose of Vegetation and Land Management program is to remove excessive vegetation, trash, and debris from creeks to reduce flood hazards and property flooding potential. The program's core services include contract management and oversight of the contract with the Texas Industries for the Blind and Handicapped, in conjunction with the Capital Area Easter Seals Organization. Core services also include citizen complaint investigation and resolution, coordination of vegetation and debris removal on flood and erosion control buyout properties, and coordination with internal and external customers related to native plant restoration efforts along segments of creeks and waterways throughout the City. Program activities are also coordinated with the Riparian Zone Restoration (RZR) program to reduce maintenance costs and improve diversity and function of riparian zones.

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9.3.1.12 Open Waterways Maintenance

The Open Waterways Maintenance (OWM) program provides removal of accumulated sediments, debris, trees, brush, and other obstructions to stormwater flow from creek beds to increase capacity. This program involves more rugged work, requiring heavy equipment and skilled City staff in response to storm clean-up needs and citizen complaints. Figure 9.3.1-7 shows the Open Waterways Maintenance crew at work.

Figure 9.3.1-7 Maintenance crew clearing debris at the Lakewood bridge crossing

9.3.1.13 Storm Drain Cleaning

The Storm Drain Cleaning program provides inspection, maintenance, and cleaning services for the City's estimated 32,000 inlets and associated storm drains, as well as maintenance for bar ditches along roadways. The goal of this program is to reduce street flooding and to protect water quality by removing accumulated sediment, trash, and debris. Figure 9.3.1-8 shows trash being removed from a storm drain inlet. Inlets are inspected on a two-year rotation or in response to citizen requests. Inlet filter devices have been installed in approximately 100 inlets within the entertainment district and those devices are inspected on a weekly basis.

Figure 9.3.1-8 Field Operations worker cleaning trash caught in a storm drain

9.3.1.14 Storm Drain Rehabilitation

The Storm Drain Rehabilitation program provides for installation and repair of storm drains, inlets, and concrete drainage structures in order to keep them in reliable and working order. The program addresses unplanned, minor storm drain improvements required for new Public Works projects and upgrades to existing infrastructure in order to mitigate flooding. These projects both result from citizen complaints, but also include planned small-scale storm drain projects that are small enough to not require construction through a Capital Improvement Program project. The purpose of this program is to ensure adequate flow capacity to protect lives and minimize flooding to property, homes, and roadways. Figure 9.3.1-8 shows trash being removed from a storm drain inlet.

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9.3.2 Existing Erosion Control Programs

The Watershed Protection Department currently has two programs that address erosion control issues, which are discussed below.

9.3.2.1 Stream Restoration Program

The purpose of the Stream Restoration program is to create a stable stream system in order to decrease property loss, protect infrastructure, and increase the beneficial use of waterways. The program achieves this by stabilizing local erosion problems and restoring long reaches of creeks on both private (within a drainage easement) and public land. The Stream Restoration program is responsible for identification and assessment of customer erosion problem complaints, problem databases, inspection reporting, and other information-related matters. It is responsible for design and management of projects for both large-scale capital projects, which are constructed through capital improvement projects, and for smaller-scale erosion projects, which are constructed by two in-house Erosion Repair Crews. The Stream Restoration program is also responsible for erosion hazard property acquisition.

9.3.2.2 Erosion Repair Crew

The Erosion Repair Crew supports the Stream Restoration program through the regular maintenance and installation of small-scale creek erosion control projects. These projects, like the larger-scale capital improvement projects, favor the use of natural engineering designs and biorevetment procedures when possible. This program allows for highly efficient and cost-effective implementation of priority channel maintenance projects throughout the City of Austin. The Stream Restoration program staff selects priority stream reaches that are appropriately sized for crew installation, then designs and oversees the project construction for the two WPD Erosion Repair Crews. Figure 9.3.2-1 depicts work done by the Erosion Repair Crew.

Figure 9.3.2-1 East Bouldin Creek at Gillis Park before (left) and after (right) the Erosion Repair Crew's work

9.3.3 Existing Water Quality Programs

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Programs targeting water quality solutions are those that attempt to limit the introduction of pollutants to receiving waters or prevent accidental contamination, and are listed in Table 9.3.3-1.

Table 9.3.3-1 Existing Water Quality Protection Operating Programs

Existing Water Quality Protection Operating Programs	
Intergovernmental Compliance	Watershed Education
Surfacewater Evaluation	Stormwater Compliance
Groundwater Evaluation	Water Quality Planning
Endangered Salamander Protection	Barton Springs Operating Permit
Watershed Modeling and Analysis	Underground Storage Tanks
Stormwater Quality Evaluation	Lady Bird Lake Maintenance
Stormwater Treatment	Environmental Policy

9.3.3.1 Intergovernmental Compliance

This program is intended to ensure compliance with all federal permits, including the City's current Municipal Stormwater National Pollutant Discharge Elimination System (NPDES) permit and all federal requirements regarding endangered species. The City's NPDES permit is a requirement of the Federal Clean Water Act. The permit requires the City to prohibit non-stormwater discharges into the municipal storm drain system, and to implement controls to reduce the discharge of pollutants in stormwater runoff to the maximum extent practicable. This permit requires coordination and interaction with existing Industrial and Construction NPDES permits held by public and private entities. This program also includes elements to ensure the City's compliance with federal endangered species regulations. The City of Austin also voluntarily participates in regional water quality protection efforts overseen by the Texas Commission on Environmental Quality (TCEQ) including the Total Maximum Daily Load program to address impairments identified on the TCEQ Integrated Report as required by Sections 303(d) and 305(b) of the Federal Clean Water Act.

9.3.3.2 Surfacewater Evaluation

The Surfacewater Evaluation program monitors creeks and lakes to determine water quality status and trends, reviews development projects for Critical Environmental Features (CEFs), primarily wetlands and vegetation features; it also performs monitoring for the Environmental Integrity Index, a gauge of creek health. The surfacewater program restores riparian areas, mostly on City property, including through capital improvement projects. They organize volunteers and provide outreach. Figure 9.3.3-1 shows sediment samples collected for analysis. Other services include reviewing TCEQ wastewater discharge permits for potential impacts, performing water quality studies on specific

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issues, implementing the Invasive Species Management Plan, managing aquatic vegetation in Lake Austin, and administering the natural aquatic plant restoration program in area lakes.

Figure 9.3.3-1 WPD scientist collects sediment samples

9.3.3.3 Groundwater Evaluation

The Groundwater Evaluation program provides technical assistance in the area of hydrogeology for WPD, as well as other departments in the City. This group provides development review for geologic CEFs and evaluates and oversees void mitigation when voids are discovered during development operations. As required under the TCEQ Edwards Aquifer Rules, they review Water Pollution Abatement Plans and Organized Sewage System Collection Plans. They monitor groundwater as required by the TPDES permit program, and also for Water Treatment Plant #4 and the Jollyville Transmission main. The Groundwater Evaluation program performs dye studies to determine groundwater flow paths, as well as other hydrogeological evaluations required by the Balcones Canyonland regional permit, under the Endangered Species Act, and by the development review process.

9.3.3.4 Endangered Salamander Protection

The purpose of the Endangered Salamander Protection program is to provide monitoring, impact assessments, and captive breeding of endangered aquatic species for the citizens of Austin and regulatory agencies in order to ensure the survival of the species, promote recovery of the species, and at the same time, allow the continued use of Austin’s unique natural resources.

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Core services provided by this program include management of the Barton Springs Salamander, Austin Blind Salamander, Jollyville Plateau Salamander, population surveys, habitat surveys, CIP aquatic salamander impact reviews, Barton Springs pool maintenance, Barton Springs pool improvement, Barton Springs Pool Master Plan project management for short term water quality projects funded by the Master Plan, review of potential impact of state and federal legislation, and Endangered Species Act compliance reports. Figure 9.3.3-2 shows a Jollyville Plateau Salamander.

Figure 9.3.3-2 Jollyville Plateau Salamander

This program administers the Texas Parks and Wildlife Department permit compliance reports, the captive breeding program, and rescues and spills response. It also monitors for the federally threatened Jollyville Plateau Salamander and the federally endangered Austin Blind Salamander, evaluating stressors, habitat characteristics, and population parameters. These activities are necessary to keep the City of Austin in the best position possible regarding federal restrictions in and around salamander habitat.

9.3.3.5 Watershed Modeling and Analysis

The Watershed Modeling and Analysis program provides technical support for programs in terms of study design, statistical analysis, and watershed and water quality modeling. This program administers the Total Maximum Daily Load program for impaired City waterways, as determined by TCEQ, overseeing the stakeholder process to ascertain actions necessary to ameliorate bacteria problems in urban streams. Services also include managing a field sampling database and providing technical support for analysis tools for other programs in the department.

9.3.3.6 Stormwater Quality Evaluation

The Stormwater Quality Evaluation program provides information on stormwater runoff quality and pollutant removal efficiency to aid in the evaluation and implementation of environmentally beneficial projects. Services provided by this program include stormwater quality and quantity evaluations, stormwater quality and quantity monitoring, shallow groundwater quality monitoring, best management practices (BMP)

Figure 9.3.3-3 Stormwater quality monitoring

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performance evaluations, dry-weather screening, and watershed modeling to support Master Planning activities. Figure 9.3.3-3 shows a stormwater quality monitoring station.

9.3.3.7 Stormwater Treatment

The Stormwater Treatment program designs, implements, and evaluates stormwater treatment systems in order to reduce pollutions in our creeks, lakes, and aquifers. This program manages the planning, design, and construction of structural water quality controls implemented as capital projects, and is responsible for planning, design, and construction of urban water quality retrofits per the 1991 Urban Watershed Ordinance. It also develops technical criteria for the Environmental Criteria Manual.

9.3.3.8 Watershed Education

The Watershed Education program provides instruction and educational materials to students, teachers, and the general public so they have the information needed to make informed decisions about reducing pollution in our watersheds. The program's goal is to increase citywide awareness of the causes of non-point source (NPS) pollution and to encourage the reduction of pollutant loads entering Austin's receiving waters. Program elements include:

- NPS Pollutant education campaigns and initiatives
- Citywide Integrated Pest Management program (IPM)
- Earth Camp for Elementary Students
- Grow Green Landscape program
- Green City initiative
- Clean Creek Campus
- Keep Austin Beautiful (KAB) creek cleanup coordination
- Scoop the Poop
- Signage for watershed education

Figure 9.3.3-4 Watershed Education program element logos

9.3.3.9 Stormwater Compliance

The purpose of the Stormwater Compliance program is to respond to pollution incidents and inspect and permit businesses, TPDES industrial and high risk facilities and activities, and specific non-stormwater discharges. The program provides technical environmental regulatory/remediation advice for City departments, policy makers, the community, and regulatory agencies in order to reduce pollution in our creeks, lakes, and aquifers.

One activity of this program is the Storm Sewer Discharge Permits (SSDP), which is primarily responsible for inspection and permitting of specific commercial and industrial businesses within the Austin City limits to prevent or mitigate polluting discharges to the City storm drains and waterways. Site inspections are conducted to evaluate waste handling, storage and disposal practices, maintenance activities, and operational condition of water quality controls. This group is also responsible for review of non-stormwater discharges to the city storm drain system and waterways to prevent polluting discharges.

Another activity includes the Emergency Spills and Complaints Response group (ESCR), which responds to hazardous and non-hazardous material spills and citizen pollution complaints within the Austin City limits and the five-mile ETJ to prevent and mitigate polluting discharges to City storm drains and waterways. ESCR staff manages a 24-hour Environmental Hotline to ensure rapid response and reduce potential environmental impact. ESCR staff assess the potential environmental impact and determine the responsible party, identify the pollutant(s), and ensure that corrective action and preventive measures are taken. ESCR staff request and review sample results and remediation plans as needed.

The Contaminated Site Cleanup activity (CSC) is operated in conjunction with the Emergency Spills and Complaints program. The CSC activity provides remediation and disposal of hazardous/toxic materials found abandoned on City road rights-of-way, and on City properties not operated by a specific department when the responsible party cannot be located. The CSC activity also responds when a responsible party can ultimately be found but the situation is critical and cleanup must be done quickly. The activity consists of a spill remediation contract and a spill material disposal contract with private waste management firms. These contracts are managed on an as-needed basis by the ESCR staff. Figure 9.3.3-5 shows an auto-repair site prior to cleanup.

Figure 9.3.3-5 Site cleanup needed at an auto shop

9.3.3.10 Water Quality Planning

The Water Quality Planning program provides planning assistance and GIS analysis to WPD program managers, the public, and other governmental agencies to optimize policies, programs, and regulations for watershed protection. The Water Quality Planning program evaluates past trends and emerging solutions to shape future policies, activities, and development patterns to help prevent problems, avoid unnecessary costs, and ensure healthy watersheds, public benefit, and water supply protection. This program coordinates with regional planning efforts such as the Barton Springs Regional Water Quality Plan. This group provides support to the Watershed Master Plan and the Imagine Austin Comprehensive Plan through GIS analysis, modeling, and mapping support. The Water Quality Planning group takes the lead on development of new water quality regulations such as the Watershed Protection Ordinance revisions, and provides support to the Environmental Policy program in the review of Utility Service Extension Requests and ETJ releases. Figure 9.3.3-6 shows a series of stakeholder meetings held as part of the adoption of the new Watershed Protection Ordinance (WPO).

Figure 9.3.3-6 The process of developing the new WPO included two years of stakeholder meetings.

9.3.3.11 Barton Springs Zone Pond Operating Permits

The Pond Operating Permits program ensures that water quality controls within the Barton Springs Zone are maintained regularly and meeting pollutant concentration requirements. Annual permits and regular inspections are required for water quality controls that treat newer commercial and/or multi-family development in the Barton Springs Zone and Barton Creek watershed. This program was developed in conjunction with the City of Austin's 1991 Composite Ordinance to protect the Springs and Creek. At present, annual permits are required only within the Barton Creek watershed and the Barton Springs Zone. The program goal is to prevent recharge water quality degradation with respect to toxics, nutrients, organics, and sediment. Information from inspections and permitting is entered into the Barton Springs Operating Permit program's pond database. Pond maintenance is the responsibility of the property owner. A "Notice of Violation" letter is mailed to the non-compliant property owner.

9.3.3.12 Underground Storage Tank Management

The Underground Storage Tank permitting program is part of the Land Use Review division of the Development Services Department. This program is responsible for issuing permits and conducting inspections to ensure the safe storage of hazardous substances in underground storage tank (UST) systems.

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Plans for all UST sites are reviewed for compliance with City of Austin regulations, which require that all USTs be registered and inspected. Inspections are conducted annually as well as during alteration, removal, and/or new construction of UST systems. Tank construction activities are inspected during groundbreaking, pipe installation, tank installation, console installation, and during final acceptance. There is also a public education component, focusing on best management practices (BMP) for safe handling and storage of hazardous materials. This program maintains a complete database of historical information, as well as a current inventory with leak detection and inspection results. Figure 9.3.3-7 shows the installation of an underground tank.

Figure 9.3.3-7 Underground tank being installed in the Williamson Creek watershed

The City of Austin's UST program is part of the City's Water Pollution Abatement Plan as required by the Texas Water Code Section 26.177 and by the Hazardous Materials Storage and Registration Ordinance found in Chapter 6-2 of the City Code. It is also required under the current NPDES permit and the Uniform Fire Code.

9.3.2.13 Lady Bird Lake Maintenance

The Lady Bird Lake Maintenance program provides removal of trash and debris on and around Lady Bird Lake, and typically removes over 250 tons of debris annually. This program manages several booms on Lady Bird Lake that catch floating debris, most visibly at the mouths of West Bouldin and Shoal Creeks. WPD contracts with Easter Seals for trash pickup around the mouths of several urban creeks that discharge into Lady Bird Lake, and co-sponsors the Keep Austin Beautiful campaign in conjunction with the Water Quality Education program to enhance volunteer cleanups along Lady Bird Lake and Adopt a Creek program locations. Figure 9-3.3-8 shows a cleanup along the shores of Lady Bird Lake.

Figure 9.3.3-8 Field Operations crew cleans shoreline

The program has a full-time crew of three to four people who work every day barring inclement weather, or if upstream floodgates are open. In addition, multiple floating barges, two deck boats, and one small john boat are used to gather floating debris. Although the impact on water quality is primarily aesthetic, this program has high public acceptance because of the prominent visual

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pollution that is removed. Staff reports significantly reduced public complaints regarding trash on Lady Bird Lake since the program was instituted.

9.3.3.14 Environmental Policy

The Environmental Policy program provides policy development assistance and regulatory guidance to City of Austin officials, program managers, the public, and other governmental agencies to make recommendations that help shape significant City policies and represent the City in strategic areas. The Environmental Officer, who manages this program, works with the One Stop Shop to provide guidance and direction to the Environmental Review staff and to provide oversight of environmental variance requests to the Land Development Board. The Environmental Policy program acts as the liaison to the Environmental Commission, and oversees environmental compliance on complex projects in environmentally sensitive areas such as Water Treatment Plant #4 and the Jollyville Transmission Main.

9.3.4 Existing Integrated Programs

Integrated programs are those that address more than one of the WPD missions. There are five integrated programs currently in operation, as shown in Table 9.3.4-1.

Table 9.3.4-1 Existing Integrated Operating Programs

Existing Integrated Operating Programs	
Stormwater Control Maintenance	Watershed Master Planning
Drainage and Environmental Review	Data Management
Drainage and Environmental Inspection	CIP Coordination
Value Engineering	Sustainability

9.3.4.1 Stormwater Control Maintenance

This program restores and maintains water quality and detention ponds to ensure they are operating effectively, providing water quality control, flood protection, and downstream erosion control. The Detention and Water Quality Pond Maintenance and Repair program provides regular maintenance and repair of flood detention and water quality ponds managed by the City of Austin. Oversight includes flood detention ponds, sedimentation basins, sedimentation-filtration ponds, extended detention ponds, and wet ponds, as well as a variety of BMPs including filter strips, rain gardens, bioswales, and biodetention facilities. Clogging of flood detention and water quality facilities is common and can lead to severely reduced functioning. This program includes flood mitigation, water quality benefits, and aesthetic benefits through proper management of excessive vegetation in City-maintained stormwater ponds. This program also includes Residential and Commercial Pond Inspection to ensure that the many structural flood, erosion, and water quality controls required by

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City ordinance continue to function properly to protect waterways, lives, and property. Residential ponds are inspected annually and Commercial Ponds are inspected every three years. Commercial pond maintenance is the responsibility of the property owner. A "Notice of Violation" letter is mailed to the non-compliant property owner. Pond maintenance items for residential ponds are addressed by this program.

9.3.4.2 Drainage and Environmental Review

The Drainage and Environmental Review program seeks to achieve regulatory compliance for land development activities by enforcing the requirements of the City's Land Development Code (LDC), the Environmental Criteria Manual (ECM), and the Drainage Criteria Manual (DCM). The Drainage and Environmental Review program resides in the Development Services Department. The Water Quality Engineering and Drainage Review program provides engineering and construction review for preliminary plans, final plats, subdivision construction plans, and site plans in accordance with the LDC, ECM, and DCM. This program is essential to the maintenance of Austin's high water quality, flood mitigation, erosion control, environmental protection, and aesthetic standards and practices.

Technical support is provided by both the Environmental Resource Management division and the Watershed Engineering division of WPD. The Environmental Review section coordinates with the environmental related activities of the Development Assistance Center (DAC) and provides water quality, tree protection, and landscape review, as well as inspection for all site development.

9.3.4.3 Drainage and Environmental Inspection

The Drainage and Environmental Inspection section resides within the Site and Subdivision Inspection division of the Development Services Department's One Stop Shop. This group performs drainage and environmental site inspections during construction and following completion of development projects, including red-tagging development out of compliance, and overseeing the proper installation and maintenance of temporary and permanent erosion and sedimentation controls on construction sites.

9.3.4.4 Value Engineering

The purpose of the Value Engineering (VE) program is to maximize the value of the department's Capital Improvement Program (CIP) projects and engineering products, and to improve the efficiency and effectiveness of program processes and services by identifying opportunities for cost savings, cost avoidance, cost sharing, and enhancements. With the ultimate goal being to make the most use of the department's limited resources, it is important to recognize that enhanced value is not just monetarily based, but can also be found in less tangible items, such as improved function and use,

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avoidance of adverse impact, increased customer acceptance, better quality, and cost avoidance and/or deferral. The VE program includes a value engineering team comprised of highly knowledgeable and well experienced engineers who focus on identifying and recommending alternative design plans, optimal solutions, and/or cost-effective methods through detailed technical review and comment related to project scopes, preliminary engineering reports, design plans, design models, project costs, program processes and procedures, all the while ensuring compliance with various regulations and design standards. Recommendations typically include considerations related to engineering, construction, operation and maintenance components of each project or program area analyzed by the team. Aspects related to adverse impact, sustainability, stakeholder interests, and the environment are also considered as part of each review.

9.3.4.5 Watershed Master Planning

The purpose of the Master Planning program is to coordinate the integration of flood, erosion, and water quality activities for City staff and policy makers so they have the information to develop, prioritize, and implement cost effective, integrated solutions.

The Watershed Master Planning program involves coordination of comprehensive Master Planning initiatives for stormwater management at the watershed level. This program is implemented by WPD staff and includes evaluation, planning, and coordination of:

- Technical investigations
- Regulatory solutions
- Watershed planning and analysis activities
- Stormwater management goals
- Operating programs
- Solution integration

This program also coordinates WPD participation and input into the many citywide planning initiatives, including Neighborhood Planning and the Imagine Austin Comprehensive Plan.

The Watershed Master Plan program includes managing WPD rule changes to the City's technical manuals, and coordinates review of rule and ordinance changes proposed by other departments, as well as coordinating with the City's Legislative Management team on pending state legislation that could impact watershed protection. This program also creates online educational material to assist City staff and the public in their understanding of WPD programs, City rules, and regulations.

9.3.4.6 Data Management

The Data Management program is a general support program for both GIS and data management. GIS systems link digital map information with database information to allow for efficient spatial analyses. Some GIS systems development and management is provided by the CTM Department;

however staff members within this program provide GIS system development and management for the Erosion Control, Flood Mitigation, and Water Quality Protection mission programs. The immediate goal of the Data Management program is to compile and maintain accurate and complete digital map information and corresponding database information for WPD missions and functions, using consistent mapping, database structures, and GIS platforms. Figure 9.3.4-1 shows a visual representation of the relationship between WPD data and the department's organizational structure.

The Data Management program provides accurate and consistent data storage and retrieval, often in relation to GIS systems. The development of useful and accurate GIS systems requires consistent, accurate, and well-designed supporting databases. The Data Management program identifies all databases currently used, organizes them within a single, consistent database platform, and integrates them into an appropriate GIS. Ongoing activities involve updating and managing those databases and GIS systems.

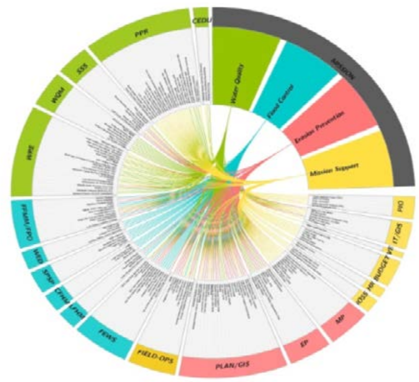

Figure 9.3.4-1 The Data Orb depicts the organizational relationships of data

9.3.4.7 CIP Coordination

The WPD Capital Improvements Program (CIP) Coordination group identifies and promotes funding for projects designed to improve public stormwater management and infrastructure. Projects are coordinated with other City of Austin departments such as Public Works, Transportation, Parks, and Austin Water and through Public-Private Partnership (P3s). This combination of resources results in minimizing capital cost and impact to the public while maximizing public benefit. The CIP Coordination group also works closely with the Capital Planning Office (CPO) to ensure that current and future fiscal year budgetary requirements are met.

9.3.4.8 Sustainability

Among the newest business/development models that has been adopted by the City is that of sustainability. Sustainability refers to the philosophy that everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit the fulfillment of the social, economic, and other requirements of present and future generations.

In recognition of this philosophy, the City has established an Office of Sustainability to inspire residents to take action and lead change for a healthy environment, excellent quality of life, and economic vitality. To further these goals, a Sustainability Liaison has been appointed in WPD to help the department meet the City's goals through innovative and forward-thinking BMPs within each of our missions.

Going forward, the goal of WPD is for the business practices that support sustainability to be integrated into all of our regulatory and programmatic solutions to our community's environmental problems.

9.3.5 Potential Program Elements

Several new integrated program elements were identified during the course of the 2001 Master Plan to address specific problems or to implement capital project solutions. A summary of the potential program elements identified in that report are listed below.

- Flood and Erosion Hazard Property Acquisition
- Grow Green Landscape Program for Water Quality
- Conservation Easement/Land Acquisition Program
- Street Sweeping for Toxic Control
- Small Scale Urban Water Quality Retrofit and Baseflow Enhancement
- Trash and Debris Control Team

The status of implementation of these potential new programs can be found in Appendix D.

9.4 Regulations

Regulations are implemented through the application and enforcement of the City of Austin's administrative codes and rules. Typical examples of regulations include impervious cover limits for new development, drainage design criteria, and industrial storm sewer discharge permitting. Regulatory solutions are effective in preventing or minimizing potential future problems such as creek instability and erosion, water quality degradation, future floodplain development, and managing future flood prevention.

The regulatory solutions inventory described in this section is a catalog of existing and potential future City regulations and rules that directly affect the Erosion Control, Flood Mitigation, and Water Quality Protection missions of the Watershed Protection Department. The following inventory of existing regulations was taken from Austin City Code Chapters 4, 10, 12, 14, 18, and 25. Title 30 also regulates development in the City's extraterritorial jurisdiction (ETJ). See Table 9.4-1 for summary of Code chapters and purpose. The majority of the regulations enforced by WPD and Develpment

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Services are found in Volume 2, Chapter 25 of the City Code, also known as the Land Development Code (LDC), which contains all regulations affecting the development or redevelopment of land. See Appendix E for a summary of the implementation status of regulatory recommendations.

Potential future regulations were identified from several sources, including City staff, consulting studies, review of existing or draft regulations from selected municipal governments, and published literature.

The City Code allows City departments to administratively create rules—also known as criteria—to provide uniform minimum standards for implementing the Land Development Code. Proposed rules must be posted for public review and comment. Following a minimum 30-day comment period, a City department may adopt a rule as proposed, a modified version, or portion of a proposed rule. Any person may appeal the adoption of a rule within 30 days after the date of adoption.

Table 9.4-1 Existing City Regulations Affecting Watershed Protection

Code Chapter	Purpose
Title 6	Restricts discharges into a watercourse; outlines federal and state requirements.
Title 6	Restricts hazardous materials and underground storage facilities.
Title 6	Restricts use of coal tar pavement products.
Title 15	Relates to Drainage Utility and fee collection.
Title 25	Land Development regulations for erosion, flood, and water quality requirements, including subdivision and site development standards.
Title 30	Companion piece to Title 25 for subdivision development in the ETJ.

Adopted rules affecting the departmental missions are contained in the City of Austin Environmental Criteria Manual (ECM) and Drainage Criteria Manual (DCM). In instances where the Code references these manuals, any development is required to comply with their criteria. Since rules are adopted via administrative process, the criteria manuals are an appropriate place for detailed technical requirements. The review and appeal process is designed to protect the effected communities from arbitrary rules, as well as rules that are technically unsound.

Finally, methods of enforcing regulations are discussed, including incentives and other options to assist the regulated community and ensure compliance.

9.4.1 Overview

The development process is a key element in Austin's ability to achieve flood protection, erosion control, and to maintain water quality. While a portion of drainage infrastructure is built by City, county, and state public works and through WPD retrofit and regional projects, the vast majority is

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planned, designed, and constructed as part of private land development. The Land Development Code and the Drainage and Environmental Criteria Manuals establish the standards under which any development occurs. As described in the Problem Area Identification Sections 3 through 7, a significant portion of the watershed problems that exist—now believed to exceed one billion dollars of need—are the result of decades of land development that occurred prior to the advent of adequate regulatory protections. This underscores the vital importance of these regulations in guarding public safety and the physical environment, and preventing unsustainable public and private community expense.

Land development regulations can either be in the form of specific development regulations (e.g., a regulation specifying an impervious cover restriction) or development planning strategies. These two items work together, with the specific regulations ensuring that development is consistent with the City's overall development strategy.

The City of Austin's development regulations apply within the city limits. Many of the development regulations also apply within the City's extraterritorial jurisdiction, or ETJ. Land development protections differ among five watershed classifications, presented in Figure 9.4.1-1. Each classification combines individual watersheds (e.g., Shoal Creek, Waller Creek, etc.) based on their relationship to Austin's drinking water supply and relative age of development. The five classifications are in turn combined into two larger groups, also shown in Figure 9.4.1-1. The Desired Development Zone (DDZ), which includes all Suburban and Urban watersheds, and the Drinking Water Protection Zone (DWPZ), which includes the Barton Springs Zone, Water Supply Suburban, and Water Supply Rural watersheds. Some development regulations are applied differently, depending upon the classification of the watershed in which the regulation is applied. Generally, regulations in the western DWPZ are more protective than those in the central and eastern DDZ due to the more environmentally sensitive geography of the west (Edwards Aquifer recharge, steeper slopes, thinner soils) and the fact that these areas drain directly to Austin's water supply in Lake Austin and Lake Travis.

Regulations in this inventory are divided into five categories, beginning with regulations affecting each of the departmental missions, followed by a discussion of factors affecting all WPD missions and incentives. The five categories are:

- Flood protection
- Erosion control
- Water quality
- Integrated regulations affecting all watershed protection missions
- Incentives and Enforcement

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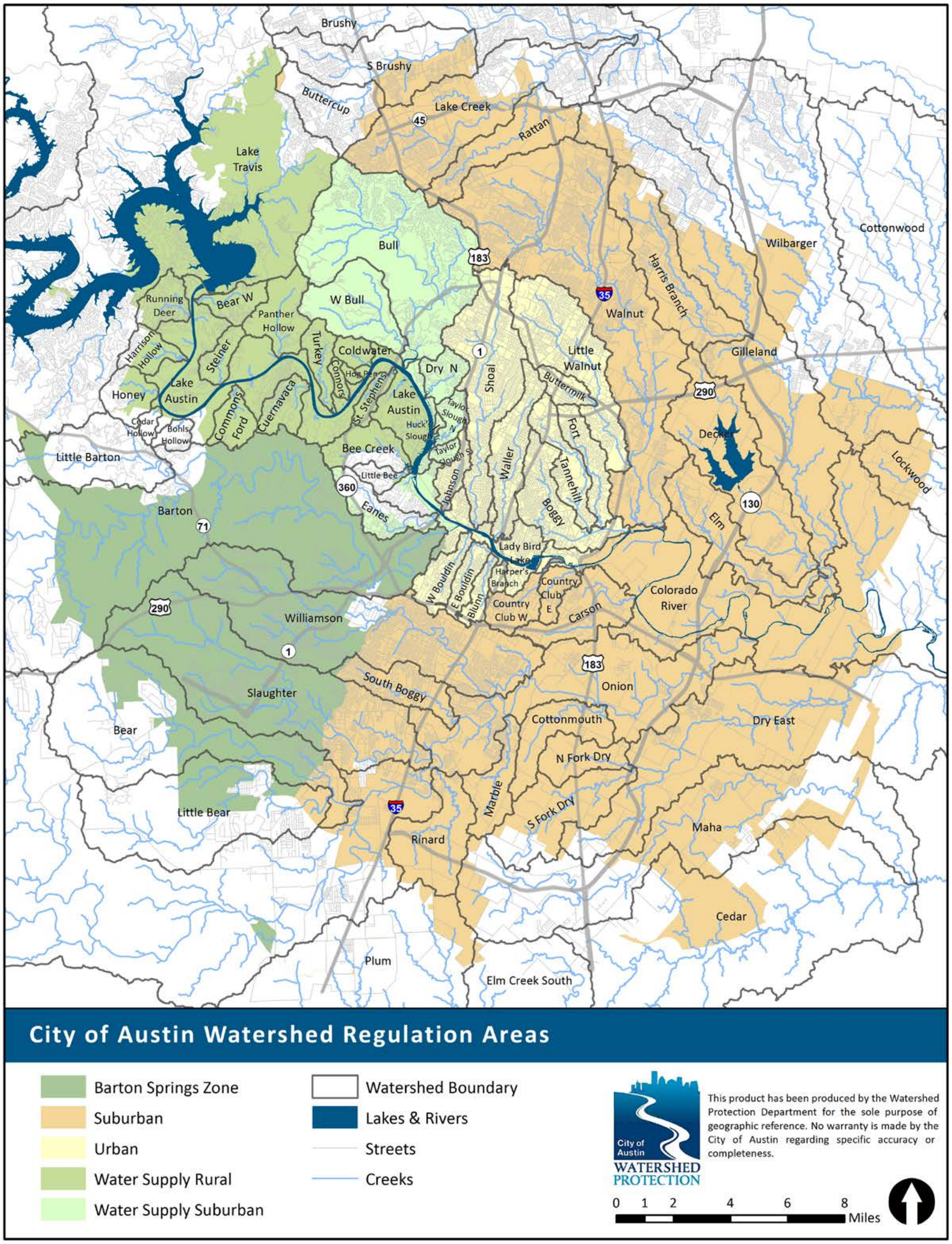

Figure 9.4.1-1 Watershed Regulation Areas (2014)

9.4.2 Flood Protection

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Drainage systems and flood protection are essential elements of the developed environment. The drainage system consists of natural and man-made conveyance and storage facilities. In the undeveloped condition, stormwater runoff storage is widely distributed and slowed across the landscape in natural floodplains, wetlands, creeks, by vegetation, and within the soil. Due to increased impervious cover and piped or channelized flows, development displaces this storage capacity and stormwater runoff travels more quickly into downstream conveyance and storage systems.

City ordinances and rules regarding flooding are contained in Chapter 25-7 of the City Code and in the Drainage Criteria Manual. The City's drainage policy governs planning and design of storm drainage facilities within the City and its ETJ. Except for the obstruction prohibitions, the City's drainage regulations and rules are implemented through the land development process. Flood protection regulations are listed in Table 9.4.2-1.

Table 9.4.2-1 Flood Protection Regulations

Flood Protection Regulations	
Prohibitions on Obstructions to Waterways	Return Interval Standards
Peak Flow Limits	Contributing Area Assumptions
Floodplain Development/Alteration Regulations	Drainage Easement Maintenance Criteria
Floodplain Modification Criteria	Stormwater Pond (Dam) Safety Requirements
Drainage Study, Floodplain, and Easement Delineation Standards	

9.4.2.1 Prohibitions on Obstructions to Waterways and Easements

The Austin City Code prohibits flow obstructions in two contexts. Section 6-5-64 prohibits any stormdrain or watercourse stoppage that results in an illegal discharge. The primary purposes of this section of the Code are preservation of water quality, assurance of adequate drainage conveyance, and proper maintenance of drainage infrastructure. Sections 25-7-3 and 25-7-4 prohibit any obstruction to a waterway except as authorized by an approved development plan. The primary purposes of these sections of the Code are to ensure adequate waterway conveyance and mitigate potential flooding. Figure 9.4.2-1 shows a flow obstruction in Bull Creek.

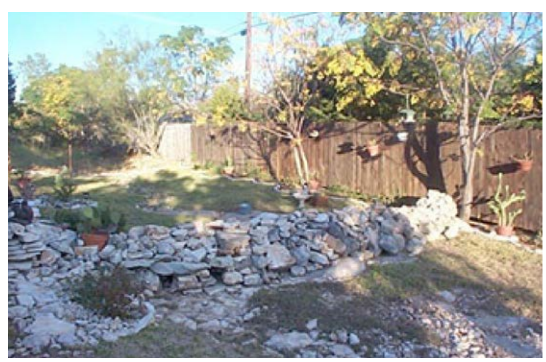

Figure 9.4.2-1 Obstructions in a Bull Creek tributary

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Potential Improvement. Flow obstructions in waterways are prohibited by Code, and most drainage easement documents also contain language prohibiting obstructions or development from being placed in the easement. Current Code does not, however, require maintenance of drainage easements in their original condition. Drainage easements are created in perpetuity and it is therefore very important to establish the appropriate language in easement documents to define the purpose of the easement, the restrictions within the easement, maintenance requirements, and the rights and responsibilities of the City and the property owner. Adding enforceable language to the City Code could be a satisfactory solution that would allow removal of flow obstructions and woody debris only in areas of bridges, culverts, and abutments, where obstructions directly influence the floodplain.

9.4.2.2 Peak Flow Limits

City Code provisions regarding peak flow require that any subdivision construction plan or site plan provide sufficient conveyance for the design flood, determined in accordance with Section 1.2.2 of the Drainage Criteria Manual (DCM). Sections 1.2.2.A and 1.2.2.D of the DCM require that peak flows from the site shall not cause increased inundation of any building or roadway surface beyond the site boundaries and that peak flow rates shall not be increased at any point of discharge from the site for the 2-, 10-, 25-, or 100-year storm frequency. Developments that discharge directly into Lake Travis, Lake Austin, Lady Bird Lake, or other portions of the Colorado River are exempt from the requirement to limit peak flows.

Peak flow regulation may be achieved by on-site or off-site storage, or by participation in the City's Regional Stormwater Management Program (RSMP). The RSMP is an alternative to on-site detention for flood mitigation purposes that uses a watershed-wide approach to analyze potential flooding problems and to identify appropriate mitigation measurements. Funds for the program are obtained from fees paid by land developers in lieu of providing on-site detention. The RSMP program is only available in select watersheds that are currently developing and have potential for flooding problems as undeveloped land is converted to impervious cover. The RSMP program is also discretionary; a staff determination establishes whether a particular project is eligible based on established criteria.

Potential Improvement. City peak flow regulations could be changed to require some flow controls for all redevelopments if detention or retention was not previously provided for the site, preferably by on-site, micro-management of storm flows via rain water catchment and/or infiltration via rain gardens. Another approach would be to require flow volume limits rather than peak flow limits; see "Flow Volume Limits" section below for more discussion. The City could also implement volumetric controls to match developed runoff volumes to existing volumes during a critical time period. This would ensure no increases in downstream peak flow and volume rates during the critical time period, thus mitigating adverse impacts at downstream locations on a watershed-wide basis.

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9.4.2.3 Floodplain Development/Alteration Regulations

There is not a federal prohibition for development in the 100-year floodplain. Instead there are requirements for permitting and flood-proofing, and safety requirements for those structures located in the 100-year floodplain. The City of Austin has imposed more stringent restrictions on development within the floodplain, which include restrictions on encroachment in the floodway and minimum finished floor slab elevations based on the FEMA-required base flood elevation (BFE).

In addition, the City of Austin is a member of the National Flood Insurance Program (NFIP), and the City's more stringent requirements help to significantly reduce flood insurance rates as well as offering other integrated erosion and water quality benefits. City Code prohibits development application approval if any proposed building on the application encroaches into the 100-year floodplain based on fully developed watershed conditions (Section 25-7-92.B). Code allows for general exceptions, special exception in the Central Business District, and exception for parking areas (Sections 25-7-93, 94, and 95). All development allowed by exception in any portion of the 100-year floodplain must demonstrate that there is no identifiable increase in flood elevations on other properties. All new construction, including additions to existing structures, must comply with flood-proofing requirements, minimum floor elevation of one foot above the fully developed floodplain, and dedication of the 100-year floodplain as a drainage easement.

9.4.2.4 Floodplain Modification Requirements

Code Section 25-8-364 and Environmental Criteria Manual Section 1.7 regulate development projects proposing to alter the floodplain. The requirements vary depending on whether the modifications are proposed for inside or outside the Critical Water Quality Zone. Floodplain modifications are prohibited in the Critical Water Quality Zone unless: (1) the floodplain modifications proposed are necessary to protect the public health and safety; (2) the floodplain modifications proposed would provide a significant, demonstrable environmental benefit, as determined by a functional assessment of floodplain health; or (3) the floodplain modifications proposed are necessary for development allowed by Code. If the proposed modification does not qualify for one of these three exemptions, then the applicant must seek a variance from the Land Use Commission. For proposed floodplain modifications outside (beyond) the Critical Water Quality Zone, a fourth exemption is provided if the proposed modification is located in an area determined to be in poor or fair condition by a functional assessment of floodplain health.

Any alterations allowed in the floodplain or Critical Water Quality Zone must be located, designed, and maintained to retain the integrity of protected riparian areas and minimize damage to the physical and biological characteristics of such areas. In addition, all development in any portion of 100-year floodplain must demonstrate no identifiable increase in flood elevations or erosion impacts on other properties.

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9.4.2.5 Drainage Study, Floodplain, and Easement Delineation Standards

The design of storm drainage and flood mitigation systems may be based on any of the numerous methods of rainfall-runoff computation available. The Rational Method is accepted as adequate for drainage areas totaling 100 acres or less. The Soil Conservation Service's (now called the National Resources Conservation Service) hydrologic methods should be used for drainage areas larger than 100 acres, but may also be used for drainage areas of any size. These methods are available in a variety of programs. The U.S. Army Corps of Engineers' Hydrologic Engineering Center's (HEC) programs are the most widely used.

Properties proposed for development are required to dedicate a public easement or right-of-way for a drainage facility, open or enclosed, and stormwater flow to the limits of the fully developed 100-year floodplain. Easement delineation during the land development process is currently based on the size of channel required and the assumption that the channel is frequently maintained. The general classifications for channels are natural channels and new or altered channels. Natural channels include all watercourses that have been carved by nature through erosion. New or altered channels are constructed or existing natural channels that have been significantly altered by human effort (e.g., straightened, armored, denuded of trees, etc.). The channels are required to be designed for the 25-year storm with provisions for the 100-year storm within dedicated easements or rights-of-way.

Potential Improvement. Drainage easements for natural and altered channels would best be sized based on assumptions of a naturally vegetated or less frequently maintained channel (rather than a frequently maintained channel) in order to maintain natural floodplain function and preserve ecological integrity. Additionally, a frequently maintained channel requires expensive and destructive mowing and vegetation control in perpetuity, degrading water quality and causing unnecessary erosion. Development projects proposing floodplain modifications are required to be designed to accommodate existing and fully vegetated conditions. Future improvements to channel design criteria in the DCM could include additional ways to encourage or require fully vegetated channels. Sizing drainage easements based on natural vegetation could require the dedication of wider easements in some cases.

9.4.2.6 Return Interval Standards

Return interval standards for infrastructure design influence the level of flood risk and the frequency of events for which parking areas, streets, and other land uses may become temporarily unusable due to flood storage. The greater the storm return interval used for a design, the less frequently it is likely to flood. For example, an area served by a storm drain system built for the 25-year design flood will experience fewer flood events, on average, than one served by a system designed for the 10-year event. But infrastructure built for larger storm events costs more (e.g., larger pipes, etc.)

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and hydraulic flows from systems built for larger storms are more powerful (erosive), requiring more attention to downstream impacts.

The impact of any storm is also dependent upon the land area upstream of the site. Sites with larger contributing land area upstream are also more likely to flood, because more water can drain to the site. Assumptions regarding contributing land are discussed in the following section, with this section focusing on return intervals. The DCM establishes these return interval standards for drainage facilities within the City of Austin and its ETJ, in the Table 9.4.2-2.

Table 9.4.2-2 Return Interval Design Standard

Drainage System Component	Return Interval Design Standard
Street curbs, gutters, inlets, storm drains capacity	25-year
Conveyance	100-year
Peak flow limits	2-, 10-, 25-, and 100-year
Source: City of Austin DCM	

9.4.2.7 Contributing Area Assumptions

The DCM establishes floodplain and easement delineation standards, as discussed above in "Drainage Study, Floodplain, and Easement Delineation Standards." Floodplains must be delineated for any location with a contributing area of 64 acres or greater. For areas of flow with less than 64 acres of contributing area, no floodplain shall be defined. However, any proposed concentrated flow necessitates the dedication of a drainage easement. The floodplain must be determined based on the projected fully developed, future condition of the upstream contributing area. Zoning maps, future land use maps, and master plans are suggested sources of information regarding ultimate watershed development. Modeling for fully developed conditions is done by WPD staff and provided to property owners for use in these calculations.

9.4.2.8 Drainage Easement Maintenance Criteria

The DCM establishes storm conveyance and flood control design and maintenance criteria. Criteria include specifications for component construction, box culvert and bridge construction, maximum roadway inundation during the 100-year storm, maintenance, access, landscaping, non-erosive conveyance, lining, mechanical systems, and signs. A professional engineer registered in the State of Texas must certify all designs.

Potential Improvement. Existing criteria do not necessarily provide adequate easement widths to provide proper maintenance access. Improved drainage easement width criteria would address this problem and ensure adequate, safe room for cost-effective maintenance by City crews.

9.4.2.9 Stormwater Pond (Dam) Safety Requirements

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Stormwater pond safety requirements exist to ensure that the design of all stormwater management ponds meet safety standards regarding the design of the spillway, embankment, and appurtenant structures. They are defined in DCM Section 8.3.4.B. Any hydraulic structure designed to impound stormwater that has a height greater than or equal to six feet at any point along the perimeter of the stormwater management (SWM) pond is classified as a dam and must be designed to safely pass 75% to 100% of the probable maximum flood (PMF) depending on dam size and hazard level. This requirement is intended to protect persons and property downstream of the stormwater management pond.

9.4.3 Erosion Control

Erosion occurs in stream banks, streambeds, and upland areas when sediment or other material is transported from its current location by wind or water. In Austin, erosion occurs primarily through water transport. The effects of erosion include streambank destabilization and failure, loss of adjacent property, filling of receiving water bodies, increased channel maintenance requirements, and water quality degradation from increased suspended sediment and other pollutants. Figure 9.4.3-1 depicts erosion along Shoal Creek. Regulations that impact erosion are listed in Table 9.4.3-1, and are discussed below.

Figure 9.4.3-1 Erosion in Shoal Creek

Table 9.4.3-1 Erosion Control Regulation and Practice

Erosion Control Regulations and Practice	
Erosion Hazard Zone Requirements	Cut and Fill Limits
Shoreline Modification and Dredging	Design Storm Runoff Detention
Construction-Phase Controls	Drainage Design Criteria
Revegetation Requirements	

9.4.3.1 Erosion Hazard Zone Requirements

Erosion processes such as stream bank erosion, slope failure, gully formation, channel down-cutting, and widening can threaten resources along waterways. In this context, a “resource” may include roads, buildings, fences, utilities, improved trails, other infrastructure, or any feature of appreciable

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value. These erosion processes are often unanticipated and can become accelerated with land use changes. The City of Austin spends millions of dollars to stabilize channels where resources are threatened by erosion. In most cases, the establishment of an Erosion Hazard Zone based on anticipated channel changes would have protected these resources from harm. Therefore, the 2013 Watershed Protection Ordinance required that an Erosion Hazard Zone analysis must be performed whenever a proposed project is within 100 feet of a waterway with a drainage area greater than 64 acres or the project is located where significant erosion is already present.

The procedure for delineating an Erosion Hazard Zone is described in Appendix E of the Drainage Criteria Manual. The methodology is based on a report completed for the City of Austin that utilized data from previous geomorphic surveys and measurements of historic channel cross-section geometry changes in Austin streams. Once the analysis is complete, the resulting Erosion Hazard Zone provides a boundary outside of which resources should be placed to avoid the potential impacts of stream erosion.

If resources cannot be placed outside of the Erosion Hazard Zone, the limits of the Erosion Hazard Zone can be revised where engineered protective works are provided. Stream bank stabilization must be designed to withstand the 100-year flood event. In cases where the Erosion Hazard Zone cannot be avoided or revised via channel stabilization, the structural design of proposed improvements within the Erosion Hazard Zone boundary must be adequate to withstand loadings for the eroded conditions during the 100-year flood event and not create a public health and safety hazard if exposed. Stream stabilization and protected features within the Erosion Hazard Zone must comply with all other City Code requirements and shall not create adverse impact by redirecting flow, reducing conveyance, collecting debris, degrading water quality, or damaging ecological health in the riparian zone. Figure 9.4.3-2 shows a schematic of an Erosion Hazard Zone.

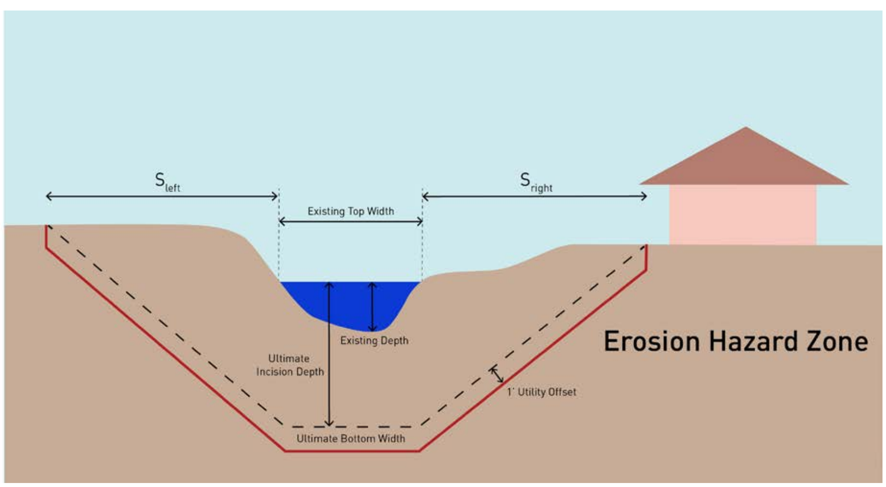

Figure 9.4.3-2 Erosion Hazard Zone Schematic

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Potential Improvement. The 2013 Watershed Protection Ordinance introduced requirements for the delineation of an Erosion Hazard Zone, as well as criteria for engineered structural protective works when resources cannot be placed outside of the Erosion Hazard Zone. As these Erosion Hazard Zone requirements have only recently been established, the success of their implementation could be monitored and evaluated in the future.

9.4.3.2 Shoreline Modification and Dredging

Shoreline modifications and dredging can contribute a significant load of soil and rock into the City's lakes. Vertical bulkheads on the shoreline disconnect the land and water, and decrease ecological function, including erosion prevention and water quality improvement provided by riparian areas. Approximately 50% of the shoreline of Lake Austin is impacted by vertical bulkheads. In 2008, WPD revised the Land Development Code to adjust the methodology for measuring the Critical Water Quality Zone (CWQZ) of the Colorado River. The CWQZ of the Colorado River is now measured from the shoreline ("ordinary high water mark") rather than from the centerline (as before the revisions), which provides extensive protection to riparian buffer zones along the river. In 2011, the Watershed Protection Department completed significant changes to the Land Development Code and the ECM to address issues regarding shoreline modifications and access on Lake Austin, Lady Bird Lake, and Decker Lake. These changes include criteria for shoreline stabilization, boat docks, and lake access devices such as trams or incline elevators. New vertical bulkheads were prohibited and code requirements were replaced with a variety of sloped shoreline stabilization options that minimize wave return, prevent erosion, improve water quality, and maintain riparian area function while providing property owners with varying landscape aesthetic choices.

Potential Improvement. In 2013, a task force of varied stakeholder interests completed a report detailing management objectives for Lake Austin. The Lake Austin Task Force consensus recommendations include identifying the potential source of increasing algae blooms in the lake, updating shoreline development regulations, and identifying new staff that can coordinate management issues on Lake Austin across all effected City departments.

9.4.3.3 Construction-Phase Controls

One of the most environmentally vulnerable periods in the land development process occurs when vegetation is cleared and a site is graded to achieve a more buildable landscape. During the clearing phase, the potential for erosion increases sharply due to the removal of the vegetative cover, disturbance of the natural soil structure, and changes in soil slope and location. Eroded soils are transported off-site into drainageways, streams, and potentially the Edwards Aquifer. Construction-phase controls, depicted in Figure 9.4.3-3, are used to mitigate these potentially destructive occurrences.

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The City Code requires construction-phase controls. Requirements include provisions for exposed soils, limitations on runoff through disturbed areas, and permanent site stabilization.

The details of these controls are contained within the Environmental Criteria Manual (ECM) Section 1.4. Phasing is required for projects with limits of construction over 25 acres to restrict areas of disturbed soil. Erosion control plans must be prepared and certified by either a Licensed Professional Engineer (PE) or a Certified Professional in Erosion and Sedimentation Control (CPESC). Certified inspectors must perform inspection and complete an inspection log every seven days or after a storm event of a half-inch or greater. The City currently has no regulations specifically controlling the storage of polluting materials at a construction site.

Figure 9.4.3-3 Construction phase controls

9.4.3.4 Revegetation Requirements

City Code requires revegetation of areas disturbed by development activities. The reestablished vegetation serves to protect the ground surface from storm runoff and wind erosion. Recent revisions to the ECM address specific standards for revegetation timing, grading requirements, soil and seed mix specifications, and fertilizer application. Temporary stabilization of soil is required when activity is dormant for 14 days or longer, and permanent stabilization is required within 48 hours of achieving final grades so as to limit the time soil is exposed to potential erosion. Special provisions are available during times of drought to time the revegetation so as to not waste water. Figure 9.4.3-4 shows successful revegetation.

Figure 9.4.3-4 Successful revegetation of a utility line in Williamson Creek watershed

9.4.3.5 Cut and Fill Limits

Cut and fill limits are restrictions upon the depth and volume of material that can be excavated from or added to a site. These serve to discourage construction on excessively steep topography

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and reduce the amount and volume of soil exposed during the construction phase. Limiting development to flatter areas reduces upland suspended solids, nutrient, and toxic loads by reducing the potential for sediment migration. It also preserves the natural and traditional character of the land, a longstanding goal for watershed protection and urban design.

City Code Sections 25-8-341 and 342 prohibit cut and fill more than four feet deep, except for specified purposes, and except in the Urban watersheds. An administrative variance to eight feet of cut and fill is offered in Suburban watersheds.

Potential Improvement. Four foot cut and fill limitations could be extended to the Urban watersheds and/or to all areas outside of Imagine Austin preferred growth "centers and corridors."

9.4.3.6 Design Storm Runoff Detention Requirements

City regulations currently require that new developments limit two-year post-development peak flows to be no greater than two-year pre-development peak flows. Runoff from 1- to 2-year storm events has been found to drive the channel formation process. Increases in peak flows and runoff volume from development can thus cause downstream channel erosion and damage to property and the environment. The two-year peak flow control requirement is designed to limit this damage. Developments typically meet this requirement by providing runoff detention to extend the release of the increased post-development runoff volumes over a longer time interval. The requirement that development provide water quality controls also serves to protect downstream waterways (See "Water Quality Capture Volume" below), but not all development which affects hydrology must provide these controls.

Potential Improvement. Current peak flow regulations do not reflect the modern state of science knowledge regarding channel erosion. Current science shows that volumetric controls that either reduce runoff volume or release flows below two-year peak rates better prevent erosion. Studies suggest that existing water quality controls can provide much of the volumetric control needed to reduce channel erosion. Specific criteria should be developed for construction projects that may not include water quality controls, but alter hydrology and potentially increase erosion in the receiving channel (e.g., storm drain upgrades, regional ponds). Projects should be designed such that peak flows, runoff volumes, and flow durations do not adversely impact channel stability. This would be demonstrated with a long-term continuous simulation of excess stream power, shear stress, or sediment transport capacity of the receiving channel. Alternatively, a sediment yield analysis using a probability weighted discrete storm could be utilized. In addition to general channel stability impacts, the potential for localized erosion from infrastructure that interfaces with the channel (e.g., storm drain outfalls, utilities, creek crossings, bridges, etc.) should be mitigated.

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9.4.3.7 Drainage Design Criteria

Current regulations for channel design to minimize erosion are for maximum velocity limits.

Potential Improvement. An improved approach would be to require that an erosion assessment be conducted, which would be used to inform a project's design to limit erosion based on shear stress and sediment transport capacity. The design would include geomorphic criteria for channel design, an inset channel for low flow storms, bankfull events within the larger overflow channel, criteria for the appropriate roughness coefficient to create channels that accommodate flows with natural channel morphology, and vegetation so that maintenance requirements are reduced and ecological services are maximized. Additional improvements include the development of a procedure for stream restoration design that provides channel stability, flood conveyance, and ecological function and design criteria for hydraulic structures such as grade controls, rock structures, and bank stabilization.

9.4.4 Water Quality Protection

Austin's quality of life is closely linked to the environmental integrity of its local water resources. As with flood and erosion, water quality problems primarily stem from changing land use conditions (primarily urbanization) that modify watershed hydrology, disrupt aquatic habitat, and increase the level of pollutants in waterways. Regulations provide effective solutions for preventing or mitigating many future watershed problems resulting from development. Some of these regulations even help correct existing problems from past development. Water quality protection regulations are listed in Table 9.4.4-1, and are discussed below.

Table 9.4.4-1 Water Quality Protection Regulations

Water Quality Protection Regulations	
Pollution Prohibition	Industrial Storm Sewer Discharge Permits
Litter and Sanitation Laws	Hazardous Materials
Animal Regulations	Wastewater Regulations
Municipal Solid Waste	Water Quality Controls
Fertilizer, Integrated Pest Management, and Landscaping Standards	Void and Water Flow Mitigation
Turf and Landscaping Regulations	Pollution Attenuation Plan
Street Sweeping	

9.4.4.1 Pollution Prohibition

The National Pollutant Discharge Elimination System (NPDES) program requires that the City prohibit unauthorized non-stormwater discharges. Such discharges can have a significant negative impact on water quality and public and environmental health. Pollution prohibitions are contained mostly in Title 6-5 of the City Code. They forbid the discharging or placing of pollutive materials (litter, sewage, industrial waste, etc.) into the water supply, or into a water treatment or distribution system. The Code includes specific prohibitions related to marine toilets and holding tanks.

Potential Improvement. The general prohibition on water pollution contains confusing references to different activities and locations within the City of Austin. An improvement would be to make simple and consistent references to water pollution-related activities, types of material, locations, and resulting conditions.

9.4.4.2 Litter and Sanitation Laws

Most litter decomposes, and when this takes place in water, the decomposition process creates oxygen demand. The oxygen demanded by decomposition leaves less oxygen available for water flora and fauna and can cause die-offs, stagnation, and algae problems. Litter is also a direct threat to aquatic flora and fauna. Litter regulations are contained primarily in Chapter 10-5, Article 3 (Prohibition on Litter), of the City Code. A prohibition against litter to waterways is cited above (Pollution Prohibition).

Figure 9.4.4-1 Litter in the Onion Creek watershed

Code §10-5-21 requires property owners to maintain their property in a sanitary condition. Garbage, rubbish, and brush must not be allowed to accumulate, nor "filth, carrion, or any other unsightly, objectionable, or unwholesome matter." Figure 9.4.4-1 depicts litter in the Onion Creek watershed.

9.4.4.3 Animal Regulations

Animal waste constitutes a significant source of bacteria pollution to waterways. Code §3-4-6 mandates that owners shall promptly remove and sanitarily dispose of feces created by their cat or dog. The City's "Scoop the Poop" pet-waste campaign works in tandem with these regulations to increase awareness of the problems with animal waste (see Water Quality Education in 9.3.3.8).

Potential Improvement. The City Code could be revised to better and more clearly describe "pooper-scooper" requirements.

9.4.4.4 Municipal Solid Waste

Leachate or solids from municipal waste placed on streets, alleys, driveways, parking lots, or sidewalks are particularly likely to enter the City's drainage system and waterways. There are three

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main sections of City Code related to solid waste:

- Garbage, rubbish, and brush
- Land use
- Technical codes

Potential Improvement. Existing regulations and services could be supplemented by a prohibition on improper storage or disposal of municipal waste, and a requirement to provide either a vegetative buffer or secondary containment for any waste storage capable of generating leachate.

9.4.4.5 Fertilizer, Integrated Pest Management, and Landscaping Standards

Current City Code regulating the application of fertilizers and pesticides is limited. In §25-8-261, public or private parks or golf courses are allowed in the Critical Water Quality Zone only if they have an approved program for fertilizer, pesticide, and herbicide use, called an Integrated Pest Management (IPM) program. ECM Section 1.6.9 requires an IPM plan be submitted for all development in the Barton Springs Zone to comply with the SOS Ordinance. IPM plans are also required in ECM Section 1.6.3 for most water quality controls that have a vegetative component: wet ponds, vegetative filter strips, biofilters, rain gardens, rainwater harvesting, and non-required vegetation. Figure 9.4.4-2 shows a garden store display of IPM products.

Figure 9.4.4-2 Local Austin gardening store

Potential Improvement. The higher standards that currently exist for the Barton Springs Zone could be promulgated throughout the City. Landscaping requirements or incentives to use native or adapted plants also reduce the need for pesticides and fertilizers. IPM plan requirements have been expanded into other areas of the City but could further improve by requiring information regarding the proper application rates, timing, storage, and disposal of pesticides and fertilizers. The plan could identify pesticides and fertilizers that potentially contribute to water quality degradation due to their chemical characteristics.

9.4.4.6 Turf and Landscaping Restrictions

To minimize the potential for water quality impacts from chemical maintenance in the Barton Springs Zone, ECM 1.6.9.2.E limits the maximum portion of any commercial, multi-family, or single-family/duplex lot that may be established as turf or landscape to 15%. Some restrictions and exceptions apply. For commercial and multifamily development in Water Supply Rural watersheds, §25-8-454 requires that 40% of a site be retained or restored in a natural state to serve as a water quality

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buffer. The buffer must also receive overland drainage from the developed portion.

9.4.4.7 Street Sweeping

The City implemented a street sweeping requirement as one of four optional pollution reduction measures in the revised Composite Ordinance for water quality protection that was passed in October, 1991. The City has no other regulations requiring street sweeping.

Potential Improvement. The City of Austin could implement regulations requiring that owners of private parking lots (commercial land uses) regularly sweep their lots.

9.4.4.8 Industrial Storm Sewer Discharge Permits

City regulations (§6-5-51) prohibit discharge of waste-containing materials in excess of specified concentrations or wastes that cause or exert certain conditions in the receiving waters (Code Section 4-1-76) unless a person has a permit issued by the Texas Commission on Environmental Quality (TCEQ) or the U.S. Environmental Protection Agency (EPA). City Code 6-5-57 speaks to the requirement of an annual stormwater permit to authorize such discharges.

Potential Improvement. Expanded regulations would more clearly identify the criteria for approval or disapproval of an industrial storm sewer discharge permit. Non-stormwater discharges could be categorized into those that would be acceptable, unacceptable, and acceptable under specified circumstances.

9.4.4.9 Hazardous Materials

Austin currently regulates hazardous material storage and spill control. Additional potential regulations affecting use and storage of hazardous materials include hazardous material traps and remediation cleanup standards.

Hazardous Material Storage and Spill Control

City Code addresses underground hazardous material storage facilities, containment and secondary containment requirements, and spill and drainage control.

Potential Improvement. City Code (Chapter 6-5 Water Quality) could be expanded to more directly require proper storage of toxic and polluting chemicals that are not regulated as underground hazardous material storage. Expanded regulations could address storage of chemicals (such as antifreeze and diesel).

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Hazardous Material Traps

Hazardous material traps (HMTs) are structural devices that are typically placed at the stream crossings of major transportation routes to capture hazardous materials spills. The traps help capture any chemicals that would be released from accidental rupture of a cargo or tanker truck. (See Capital Project Inventory for a full description of HMTs.) The City currently has no requirements for hazardous material traps.

Potential Improvement. The City could implement regulations to require hazardous material traps at appropriate locations.

Remediation Cleanup Standards

The City of Austin currently imposes no remediation cleanup standards. Both state and federal legislation establish release reporting and cleanup requirements. Federal legislation addressing remediation includes the Emergency Planning and Community Right to Know Act (EPCRTKA), the Clean Water Act, the Resource Conservation and Recovery Act (RCRA), and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Texas Water Code and the Texas Oil and Hazardous Substances Spill Contingency Plan also establish remediation standards. Texas Administrative Code Chapter 334 establishes standards for underground and aboveground petroleum storage tanks and Chapter 335 for industrial solid waste and municipal hazardous waste.

Potential Improvement. The City currently exercises its authority to implement and enforce TCEQ rules within the City's jurisdiction. This City activity could be codified by adopting equivalent regulations or by adopting TCEQ regulations by reference. City regulations could also require certification for remediation contractors similar to the TCEQ Corrective Action Project Manager (CAPM) program.

9.4.4.10 Wastewater Regulations

Wastewater regulations include requirements for service extension requests, wastewater line construction, on-site sewage facilities, and phosphorus control.

Wastewater Service Extension Requests (SERs)

Sections 25-9-33, 34, and 35 of the Land Development Code list criteria under which the Director of Austin Water may grant a wastewater service extension (SER). The AW Director may administratively approve extension requests in the Desired Development Zone (Urban and Suburban watersheds) and within the full purpose jurisdiction in the Drinking Water Protection Zone. Council approval is required for all SERs in the Drinking Water Protection Zone and outside of the full purpose jurisdiction. These latter Council requirements were instituted to direct dense development—

often served by centralized wastewater service—away from environmentally sensitive areas per the Austin Tomorrow and Imagine Austin Comprehensive Plans. The SER criteria do not currently include specific environmental considerations.

Wastewater Line Construction

Chapter 18 Article V requires property owners to repair or replace plumbing so that the maximum infiltration rate is less than 250 gallons per inch diameter of pipe per mile of pipe per day. This standard is written for the purpose of reducing excess flows into the wastewater collection system, rather than for the purpose of minimizing exfiltration into the environment. Section 25-8-361 of the City Code requires that private on-site sewer systems on lots within the Edwards Aquifer Recharge Zone comply with City Code Chapter 15-5 (Private Sewage Facilities). City Code further prohibits sewer lines within the Critical Water Quality Zone except as necessary for crossings. All wastewater line leakage is a violation of Texas Water Code.

Potential Improvement. City regulations or rules could be expanded to establish higher standards for wastewater line construction. Higher standards might include some of the elements required by TCEQ for wastewater line construction in the Edwards Aquifer Recharge Zone.

On-Site Sewage Facility Requirements

An on-site sewage facility (OSSF) is defined as one or more systems of treatment devices and disposal facilities that produce less than or equal to 5,000 gallons of waste each day and are used only for disposal of sewage produced on the site where the system is located (Texas State Health and Safety Code, Chapter 366. On-Site Sewage Disposal Systems). Texas grants authority to regulate OSSFs, including septic systems, to the TCEQ. Texas also grants TCEQ authority to designate authorized agents of OSSFs: a municipality, county, river authority, or special district.

Upon receiving status as an authorized agent of TCEQ, the City must adopt OSSF standards that meet the minimum TCEQ requirements in Title 30 Texas Administrative Code Chapter 285. The City's standards have been reviewed and approved by TCEQ and were revised and improved by ordinance in 2013. City of Austin regulations were updated in October 2013 to with additional provisions more stringent than the minimums required by TAC Chapter 285, including increased vertical separation distance from groundwater and use of specific nitrogen reduction systems for new OSSFs located over the Edwards Aquifer Recharge Zone and near Lake Austin.

Phosphorous Controls

Phosphorous control regulations are contained in Title 6 of the City Code, Sections 6-5-71 to 6-5-73. These regulations prohibit the sale or gift of household laundry detergent containing more than 0.5% phosphorus by weight within the City. These regulations prevent the entry of additional phosphorus into the wastewater system; phosphorus is costly to treat and excess phosphorus in wastewater discharge is harmful if allowed to reach receiving waters, contributing to eutrophication.

9.4.4.11 Water Quality Controls

Regulations affecting water quality controls are summarized in Table 9.4.4-2.

Table 9.4.4-2 Regulations Affecting Water Quality Controls

Regulations Affecting Water Quality Controls	
Water Quality Controls Required	Water Quality Treatment Standards
Urban Payment-in-Lieu of On-Site Controls	Water Quality Control Maintenance
Water Quality Volume Capture	

Water Quality Controls Required

Land Development Code Section 25-8-211 describes conditions under which structural water quality controls are required. The remaining design element requirements are established within the City's criteria manuals. Design standards for water quality controls are found in both the Environmental Criteria Manual (ECM) and the Drainage Criteria Manual. Water quality controls in the ECM include sedimentation-filtration, wet ponds, and retention-irrigation. Additional "green stormwater controls"—many added since 2007—include rain gardens, vegetative filter strips, biofiltration, rainwater harvesting, porous pavement for pedestrian areas, disconnection of impervious cover, and non-required vegetation.

Other innovative water quality control structures or systems to provide water quality benefits through treating stormwater runoff are also accepted if it can be demonstrated that they provide treatment to the standard required in the Land Development Code, Section 25-8-151. All water quality controls must be designed and constructed according to specifications in the Environmental Criteria Manual or else approved as an innovative runoff management practice.

Urban Payment-in-Lieu of On-Site Controls Option

Austin City Code Section 25-8-214 allows for the acceptance of a payment-in-lieu of on-site controls for Urban watersheds, as defined by Section 25-8-2 of the Land Development Code. The City recognizes that incorporating structural water quality control facilities into some Urban watershed land development projects can be difficult. In response to these challenges, Section 25-8-214(C) of the Land Development Code requires the Director to review and accept or deny projects to pay into the Urban Watersheds Structural Control Fund in lieu of on-site controls. The funds received under this program have historically and will continue to be used to study, design, implement, and construct Urban water quality improvement projects.[1]

Guidelines were established in the ECM for acceptance of funds within Urban watersheds, and define two categories to judge participation:

Type I. The City will strongly consider allowing urban developments to participate in the payment-in-lieu program if they include one or more of the following:

- Commercial development of sites one acre or less;
- Single-family development of subdivisions two acres or less;
- Development with runoff that sheet flows over pervious cover prior to being concentrated; and/or
- Development that is likely to be treated by an existing or future regional water quality facility.

Type II. Developments that include one or more of the following will in most cases be required to satisfy the water quality requirements through the use of on-site water quality controls:

- No or minimal existing impervious cover;
- Substantial redevelopment;
- Adjacent to an open channel stream; and/or
- Within 500 feet of Lady Bird Lake.

Water Quality Capture Volume

The water quality control capture volume determines the largest rainfall event and the percentage of the total annual rainfall that will be captured and treated. Amounts of runoff that are greater than the capture volume will bypass the water quality control and are discharged without treatment. Water quality volume requirements are sized to both ensure adequate pollutant capture for treatment (see next item) and to control channel-forming erosive flows.

All water quality controls within the City's jurisdiction must achieve a minimum capture volume of at least the first half-inch of runoff from the contributing area once a site reaches 20% impervious cover (calculated using the net site area, or NSA), and the volume increases based on percent impervious cover. Under the SOS regulations in the Barton Springs Zone, higher capture volumes are required to meet the pollution reduction standard of no increase in the average annual pollutant load, and there is no minimum impervious cover trigger.

[1] Payment-in-lieu is further discussed in Section 9.4.6, Incentives and Enforcement.

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Potential Improvement. Capture volume requirements could be increased as a potential modification of requirements. Proposed U.S. Environmental Protection Agency NPDES rules contemplate volume-reduction approaches whereby a site must retain some percentage of runoff volume to mimic pre-development conditions. Water quality volume requirements might be accordingly adjusted per this approach.

Water Quality Treatment Standards

Water quality treatment standards provide a minimum baseline level of pollutant treatment effectiveness to ensure that stormwater is adequately treated by structural controls before it is released to waterways. The City has established two treatment standards for water quality controls, depending on location. In all areas outside the Barton Springs Zone, these controls must provide treatment equivalent to or better than a sedimentation-filtration system designed in accordance with the ECM. In the Barton Springs Zone, the SOS Ordinance requirements set a higher treatment standard of no increase in the average annual pollutant load for 13 different categories of pollutants. The required treatment efficiency under the SOS ordinance must be determined from the estimated developed condition and baseline annual pollutant loads.

Potential Improvement. Expanded treatment regulations could establish a treatment standard higher than sedimentation-filtration for the City outside the Barton Springs Zone. One form of such a standard might be a requirement to infiltrate or otherwise retain a portion of captured stormwater on-site to promote improved creek baseflow, additional pollutant removal, and water conservation (beneficial use of stormwater as a substitute for potable water).

Water Quality Control Maintenance

The City Code currently requires the property owner to maintain water quality controls for multifamily, commercial, and industrial areas. The City maintains water quality controls for single-family and duplex residential development. The City currently has maintenance responsibilities for approximately 900 residential ponds; this number continues to increase as new development occurs. Residents and businesses within the city limits support this service through payment of the drainage utility fee.

Potential Improvement. Design standards could be modified to better facilitate water quality control maintenance and to improve access into and out of the control. City of Austin design standards for retention-irrigation controls could be modified to improve pump reliability and facilitate effective pump failure response.

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9.4.4.12 Void and Water Flow Mitigation

Criteria, standards, and specifications were adopted in 2007 for notification requirements and guidance for furnishing and installing mitigation measures for voids and water flow anomalies discovered in bedrock during excavation activities, including mitigation alternatives for use in addressing anomalous features or discrete discharge points that are observed upon initial excavation (e.g., trench) or that are discovered when trench backfill material is removed. The purpose of the mitigation is to preserve voids and water flow features while maintaining utility integrity.

9.4.4.13 Pollution Attenuation Plan (PAP)

Pollution Attenuation Plan (PAP) criteria were adopted in 2007 to establish standards for all industrial development not enclosed in a building in accordance with City Code Sections 25-8-125 and 30-5-125. The requirements are applicable within the City limits and ETJ. The purpose of PAPs is to obtain information regarding water quality best management practices (BMPs) and to establish criteria for site development and reclamation. Industrial uses defined by zoning (Code Section 25-2-5) that may require a PAP for open air operations include: basic industry, custom manufacturing, general warehousing and distribution, light manufacturing, recycling centers, resource extraction, and stockyards.

9.4.5 Integrated Regulations

Integrated regulations are those which address multiple missions rather than primarily a single mission. This section starts with a discussion of the City's Comprehensive Plan, which provides the key framework upon which other city actions are built. Specific integrated development regulations are then presented, which are designed to support the WPD's Erosion Control, Flood Mitigation, and Water Quality Protection missions. These regulations are listed in Table 9.4.5-1 below.

Table 9.4.5-1 Integrated Regulations

Integrated Regulations	
Impervious Cover Limits	Imagine Austin Comprehensive Plan
Impervious Cover Reduction	Critical Environmental Features (CEF)
Flow Volume Limits	Wetlands Protection
Disconnected Impervious Cover	Landscape Regulations
Steep Slope Limits	Tree Protection Standards
Stream Setbacks	Natural Channel Conveyance

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9.4.5.1 Imagine Austin Comprehensive Plan Considerations

Chapter 211 of the Texas Local Government Code requires municipal zoning actions to be developed in accordance with a comprehensive plan (State of Texas, Local Government Code, Chapter 211). Comprehensive planning is a planning strategy that provides a mechanism to plan for, direct, and support development and redevelopment within a community. Austin's "Imagine Austin" Comprehensive Plan contains the City's policies of growth, development, transportation, and beautification within its planning jurisdiction. Imagine Austin was adopted by City Council on June 15, 2012 in accordance with Article X Section 5 of the City Charter. Imagine Austin created eight priority programs to provide the structure and direction necessary to implement the plan. These programs build on existing initiatives and are guided by community input provided during the process to create Imagine Austin. The eight priority programs are:

1. Invest in a compact and connected Austin
2. Sustainably manage our water resources
3. Continue to grow Austin's economy by investing in our workforce, education systems, entrepreneurs, and local businesses
4. Use green infrastructure to protect environmentally sensitive areas and integrate nature into the city
5. Grow and invest in Austin's creative economy
6. Develop and maintain household affordability throughout Austin
7. Create a Healthy Austin Program
8. Revise Austin's development regulations and processes to promote a compact and connected city

There are multiple ways in which Imagine Austin and these eight priority programs can be implemented to improve flooding, erosion, and water quality, including: revising development regulations and processes; integrating nature into the city through open space acquisition and protection; and investing in infrastructure to promote compact and connected development away from flood-prone, erosion-prone, or environmentally sensitive areas. Development can be planned for areas where transportation, utilities, and services could be provided efficiently and with reduced environmental effects. Stormwater storage and conveyance can be designed and constructed for flows from anticipated land uses. One Imagine Austin action item calls for the enactment of a new Watershed Protection Ordinance to streamline and expand protection of headwaters, promote low-impact stormwater management strategies, and reduce capital expenditures required to mitigate water quality problems, erosion, and flooding. Watershed Protection staff worked with the community to prepare such an ordinance between 2011 and 2013. City Council adopted the ordinance on October 17, 2013 to achieve these goals in coordination with other Imagine Austin priorities. The eighth priority program, the "CodeNEXT" initiative to revise the Land Development Code in support of Imagine Austin, will likely make further adjustments to the Code relating to watershed protection.

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Even with potential improvements via CodeNEXT, there are several factors that limit the ability of Austin's comprehensive planning process to achieve its watershed protection goals. One of the largest factors involves the City's jurisdictional area. A comprehensive planning process occurs for the geographical area within the City's jurisdiction. However, many of Austin's watersheds, such as Barton, Onion, and Gilleland Creeks, extend into areas beyond the City's jurisdiction and include the areas in the city limits and extraterritorial jurisdictions of other municipalities, unincorporated Travis, Hays, and Williamson Counties, and special districts established by the Texas Legislature that are outside of Austin's planning processes.

9.4.5.2 Impervious Cover Limits

Impervious cover consists of surfaces that are impenetrable to water. Pavement, sidewalks, driveways, and buildings are examples of impervious cover. There is a direct link between impervious cover in a watershed and stream degradation. Significant water quality and quantity changes associated with increasing impervious cover include increases in uplands washoff of total suspended solids and other polluting constituents, decreases in baseflow volume, and increases in stormflow volume and rate, which lead to stream bank erosion and channel enlargement.

Impervious cover is typically measured as the percentage of ground surface that is impenetrable. If an area has an impervious cover of 70%, then water cannot penetrate or filter into the ground over 70% of the land area. Instead, it runs off, carrying with it any pollutants on the ground it encounters along the way. Figure 9.4.5-1 depicts high impervious cover in downtown Austin.

Watersheds with even as little as 10% to 15% impervious cover cannot support high quality streams in sensitive watersheds. As impervious cover increases from 15% to 20% of the watershed, dramatic changes in the stream flow regime and biology occur (Schueler, 1995). Impervious cover may be the single most important indicator of the effect of development on the stream system. Changes in the impervious cover in a watershed significantly change runoff volume, peak flow rate, flow duration, infiltration, baseflow volume, stream cross-section and flow line elevation, water temperature, water chemistry, and biodiversity (Schueler, 1995).

Figure 9.4.5-1 Downtown is one of the most intensely impervious areas in Austin

The latest available GIS data show a range of estimated impervious cover in the watersheds inside Austin's five-mile ETJ. The most impervious is Buttermilk Creek watershed, with about 53%

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impervious cover. Watersheds with large areas of remaining rural land have much lower totals, such as Barton (6%) and Gilleland (10%), to as low as 2% (Rinard Creek) (City of Austin, 2006). These numbers will change over time as a given watershed develops and redevelops.

City of Austin regulations directly affect impervious cover by establishing maximum impervious cover limits through both zoning and subdivision/site plan requirements by watershed. Discussion in this report is limited to watershed-related impervious cover limits.

Watershed-related impervious cover limits established by the City are a function of several factors: watershed classification, relationship to the City's drinking water supply, and type of development. The basis for calculating the allowable impervious cover in the Barton Springs Zone and in water supply watersheds is the NSA. Net site area is based on the "uplands zone," the area outside of the stream protection zones. It includes all areas with 0 to 15% slopes, 40% of areas with 15 to 25% slopes, and 20% of areas with 25 to 35% slopes. Because larger portions of steeply sloped areas are discounted, this formula discourages the construction of impervious cover on steep slopes.

Allowable impervious cover may be increased up to certain limits based on a transfer of impervious cover from the stream protection zones. The Code allows transfers of development rights based on dedication of the Critical Water Quality Zone (CWQZ) to the City, preservation of natural and undisturbed areas within the Water Quality Transition Zone (WQTZ), natural areas within the setback of a Critical Environmental Feature, and limited transfers for recreational uses and wastewater disposal.

Porous pavement for pedestrian use and restricted fire lanes is allowed to be treated as pervious area, subject to installation methods and use restrictions. The ECM was also amended in 2007 and 2014 to include specific criteria under which porous pavement can be deducted from the drainage area used for sizing a water quality control. Figure 9.4.5-2 depicts one type of porous pavement. Porous pavement is also discussed in Section 9.2.3.3 of this chapter.

Figure 9.4.5-2 Porous pavement

Impervious cover limits are implemented for roadways and residential construction during the subdivision process based on the projected impervious cover. Impervious cover limits for commercial developments are regulated through the site plan process.

Potential Improvement. To further restrict impervious cover and/or its impacts, the City could consider regulations to:

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- Reduce the allowable maximum impervious cover limit;
- Reduce the allowable transfer credit for impervious cover; and/or
- Further restrict the net site area basis for impervious cover calculations.

Another approach would be to incentivize or require the use of materials and/or structural controls to counteract the impacts of impervious cover. Examples include porous pavement, green roofs, rainwater harvesting, and infiltrating rain gardens. Such approaches might be especially useful in dense areas where the impacts of high impervious cover (on both stormwater and urban heat island) are especially acute.

A final option would be to consider an expanded system of transfers of development rights (TDRs) by which the impervious cover and/or density (e.g., via increased height) on one tract could be increased in exchange for the permanent preservation of another in a natural state. This proposed system differs from the current Save Our Springs Ordinance requirement that these impervious cover limits be met on each individual development tract. The 2005 Regional Water Quality Protection Plan proposed such a system for the Barton Springs Zone. The idea was to have an overall impervious cover maximum target met by allowing landowners flexibility in where the impervious cover was located. The plan called for maximum impervious cover targets of 10% in the Edwards Aquifer Recharge Zone and 15% in the contributing zone. Specific "preferred growth areas" (PGAs) would be designated by individual communities where higher levels of impervious cover (e.g., 45%) could be built. For each such increase in a PGA, a concomitant decrease to the 10% or 15% target would be required via purchase fee simple or through conservation easements on land elsewhere (outside the PGAs) (Naismith Engineering, 2005). (A variation of this system was approved by Council in 2007 for redevelopment; see Redevelopment Exception Options discussion below.)

9.4.5.3 Impervious Cover Reductions via Development Regulations

The level of impervious cover is associated with development size and design. Many of the City's existing development regulations increase the impervious cover required for parking, roadway width, sidewalks, cul-de-sac radii, etc. Impervious cover reduction ordinances could reduce the amount of impervious cover associated with development of specific use intensity by allowing more flexible alternatives.

Impervious cover regulations address development requirements to achieve multiple purposes: to provide safe and convenient access, to maintain green space, to provide adequate emergency access, to reduce noise, provide privacy, to provide drainage, and to provide areas for living, working, and playing;

Potential Improvement. The greatest potential for impervious cover reductions is associated with transportation-related infrastructure. Approximately 60% of the impervious cover in the urban

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environment may be associated with vehicle-oriented pavement, including streets, driveways, and parking lots.

The City could implement regulatory changes geared at reducing transportation related impervious cover in the urban environment, such as:

- Allow narrower streets
- Reduce minimum parking requirements
- Use diagonal parking, single one-way lanes between stalls, and smaller stalls
- Establish cooperative parking agreements
- Encourage underground, under building, and roof parking and multi-story garages
- Allow taller buildings in exchange for reduced building footprints
- Reduce cul-de-sac radii and require landscaped islands in cul-de-sacs

The City could also require or incentivize cluster development to locate impervious cover closer together with the aim of increasing density while decreasing the per capita or per unit amount of impervious cover. Cluster development must be linked directly to permanently preserved natural areas to be effective. See previous section for discussion of potential improvements for transfers of development rights.

Regulations to support public transit systems by providing park and ride lots, bike lanes, bike parking, and trails could be required. Growth management regulations to encourage infill of urban areas can also reduce the overall amount of impervious cover per person. Infill concepts encourage development of currently unused land that is already developed with impervious cover. These existing underused development areas can be redeveloped, rather than building in areas that are not developed currently. These areas can include, for example, parking areas and vacant lots.

9.4.5.4 Flow Volume Limits

Although there are regulations limiting peak flow rates and requiring water quality controls, the City currently places no restriction on the total volume of runoff from a site after development. Drainage Criteria Manual (DCM) Section 1.2.2.D currently regulates the effect of development on flooding through peak flow rate limits. A peak flow rate limit places a cap on the peak rate of runoff flow from a developed site. DCM Section 8.1.0 states that the development also needs to demonstrate that runoff is released at a controlled rate which cannot exceed the capacities of the existing downstream drainage systems, or the pre-developed peak runoff rate of the site, whichever is less. Compliance with this latter requirement can, for some projects, result in designs which provide a level of flow volume control to avoid conveyance issues.

A shortcoming of peak flow rate limits is that the resulting flood detention structures release larger quantities of water for a longer period of time than occurred pre-development (The development increases impervious cover, which increases runoff, which must be stored and released in the detention pond, which then meters it out for a longer period of time to prevent increased peak flow rates.). The concern is that these increased volumes and peak flow durations might cause water quality and channel erosion impacts downstream.

Potential Improvement. A potential improvement would be to require a flow volume limit which would restrict the total volume of flow from a site post-development as opposed to simply restricting the rate of flow. Thus, for a given rain event, the total volume of stormwater that runs off of a site would be restricted.

The City could also implement volumetric controls to match developed runoff volumes to existing volumes during a critical time period depending on the location within a watershed. Controlling the total volume released to pre-development levels during a critical time period ensures no increase in downstream peak flow rates and thus mitigates adverse impacts at downstream locations on a watershed-wide basis. Compliance with regulations limiting the total volume of runoff from a site can be achieved by a combination of restrictions on impervious cover and technology to retain and infiltrate stormwater runoff on site. City Code could be changed to require all or some fraction of storm runoff storage be provided on each site. Potential storage areas include rooftops, parking lots, ball fields, property line swales, parks, roadside swales, and on-site ponds.

9.4.5.5 Disconnected Impervious Cover

The impact of impervious cover on water quality, storm runoff volume, and baseflow varies based on its degree of "hydraulic connectivity." Natural landscapes feature vegetation, uneven ground surfaces, an organic mulch layer, and connection to underlying soil. Only in rare cases do they have impervious surfaces (e.g., rock outcrops). This combination serves to trap and slow runoff and promotes infiltration into the soil. During small rainfall events, most or all of the precipitation will not even reach the stream during the storm event. Instead, most will be retained on site and used by plants (through evapotranspiration) and a sizeable fraction will eventually reach the stream as baseflow over the days and weeks that follow the rain. Directly connected impervious cover in natural landscapes is almost non-existent. Figure 9.4.5-3 shows disconnected impervious cover where a vegetated swale conveys water to a storm drain inlet.

Figure 9.4.5-3 Vegetative Swale conveys runoff to inlet

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The opposite condition exists in the built environment. Where rooftops, parking lots, streets, and other hard surfaces are connected to creeks through pavement, curbs, gutters, enclosed pipes, and lined channels, runoff from impervious surfaces is delivered directly to receiving waters. The increase in velocity and volume of this runoff changes the stream flow regime, water quality, and biological integrity. A common example would be an urban roof which drains to a driveway, which drains to a concrete gutter, which drains to a drainage pipe, which directly discharges into a stream. This design leaves little ability (beyond negligible "interception" provided by the impervious surfaces themselves) for water to come in contact with and infiltrate into the soil below. Virtually all rainfall, even in a small rainfall event, would be delivered to the receiving waters. Such areas are said to have "highly connected impervious cover."

Areas with lower impervious cover are more likely to include less effective impervious cover because there are more opportunities for directing runoff onto intervening soil between the impervious cover and the creek. Hydrologists study the fraction of connected—or "effective"—impervious cover to model the relative impact of impervious cover from a site; the effective impervious portion of the site acts impervious, whereas other portions are subject to infiltration and are discounted since they act more like pervious areas. The difference between actual and effective impervious cover points to a design possibility of reducing the negative impacts of a site through deliberate disconnection. Thus, a carefully designed site can have a much lower impact on receiving waters than another site with the same, albeit directly connected, amount of impervious cover. Table 9.4.5-2 below presents comparisons of total and effective impervious cover for different land uses in Austin. See also the discussion on "Impervious Cover Disconnection" in the Capital Project Inventory.

Table 9.4.5-2 Comparison of Total & Effective Impervious Cover (IC) by Land Use

Description	Total IC	Fraction Effective IC
Single-Family Residential (< 0.5 ac)	41%	22%
Single-Family Residential (0.5 to 2.0 ac)	23%	8%
Single-Family Residential (2 - 10 ac lot)	6%	1%
Large Lot Single Family (> 10 ac)	3%	1%
Multi-family Residential	60%	54%
Commercial	69%	65%
Office	59%	54%
Industrial	57%	51%
Parks & Recreation	9%	1%
Roads/Right-of-Way	47%	40%
Source: GIS data from 2006 planimetrics, Austin, Texas. Disconnected IC calculation methodology from Technical Note #58, Watershed Protection Techniques 2(1): 282-284: "Methods for Estimating the Effective Impervious Area of Urban Watersheds." Note: impervious cover for single-family residential includes sidewalks but road right-of-way is considered separately.		

The City Land Development Code does not specifically require disconnected impervious cover. However, two provisions in the City Code promote designs that result in disconnected impervious cover. Code Section 25-8-454 requires development in Water Supply Rural watersheds to provide a natural buffer area to receive stormwater runoff. Code Section 25-8-185 requires drainage designs to maintain infiltration and recharge, overland sheet flow, and natural drainage features where possible. Enclosed storm drains are allowed only where the City determines that they are preferred.

Potential Improvement. Future disconnected impervious cover regulations might require the use of stormwater controls as described in Section 9.2.3.3 of this document (Stormwater Treatment Measures) (e.g., for commercial parking lots) or require disconnection of impervious cover where structural controls are otherwise not required (e.g., in many areas where impervious cover is less than 20%).

Regulations that promote disconnected impervious cover could include:

- Requirements to direct runoff from impervious areas and rooftops onto vegetated strips designed to retain and infiltrate runoff;
- Prohibit direct connection to the storm drain system;
- Requirements to provide grass-lined channels for stormwater conveyance;
- Requirements to provide "french drain" catchments that collect/intercept subsurface infiltration.

9.4.5.6 Steep Slope Limits

Areas of extremely slanted or steep ground surfaces are generally more vulnerable to erosion, soil loss, and associated water quality problems. Steep slope regulations limit activities in these areas with severe topographic grade and thereby avoid associated problems with erosion, sedimentation, and the disruption of natural landscape characteristics. The City regulates septic system, land development, and wastewater effluent irrigation on steep areas.

Potential Improvement. Steep slope limits do not currently apply within the City's Urban watersheds. A potential expansion of these regulations would be to extend them into these watersheds. Another potential expansion would be to prohibit utility line trenching on steep slopes where alternative locations exist. There may be some potential for increasing compliance with existing regulations for residential development.

9.4.5.7 Stream Setbacks

Stream setbacks, or "buffers," limit the placement and intensity of activities adjacent to creeks. City Code currently prohibits or limits activities adjacent to creeks within two area buffers parallel to the creek: the Critical Water Quality Zone (CWQZ) and the Water Quality Transition Zone (WQTZ).

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The buffer closest to the creek is the CWQZ. It is also the most protective, limiting development activities to only passive recreation and similar activities. The secondary WQTZ buffers require a lower intensity of development than in the “uplands” areas upslope of the buffers, depending on the watershed classification. Buffer widths depend upon the creek’s watershed classification and contributing drainage area. Barton Springs Zone, Water Supply Suburban, and Water Supply Rural watersheds all have both the CWQZ and WQTZ buffers. Urban and Suburban watersheds, the lakes, and the Colorado River downstream of Longhorn Dam have only the CWQZ buffer. A small area of downtown, Austin’s Central Business District, does not have either type of buffer.

The 2013 Watershed Protection Ordinance provided citywide CWQZ protection for all creeks with minimum drainages area of 64 acres or larger, thereby providing all smaller, “headwaters” creeks with setback protections. Except for Urban creeks, stream buffers fall into three categories based on the size of the contributing drainage area. The smallest, “minor” waterway buffers extend from 64 acres of drainage to 320 acres. Medium-sized, “intermediate” waterway buffers extend from 320 to 640 acres of drainage. And the largest, “major” waterway buffers are provided for all creeks with more than 640 acres (one square mile) of drainage.

Western watershed CWQZ buffer widths vary with the 100-year floodplain: 50 to 100 feet for minor, 100 to 200 feet for intermediate, and 200 to 400 feet for major waterways. Suburban CWQZ buffers have a fixed width of 100, 200, and 300 feet (from each side of the waterways) for minor, intermediate, and major waterways, respectively. Urban watershed CWQZ buffers vary from 50 to 400 feet wide depending on the width of the 100-year floodplain for all waterways greater than 64 acres of drainage. In Suburban watersheds, project designers may also elect to use buffer zone averaging. This concept allows the width of the buffer zone to change, as long as the average width is maintained. WQTZ buffers also vary with contributing drainage area and have a fixed width of 100, 200, and 300 feet for minor, intermediate, and major waterways, respectively.

Lake Travis, Lake Austin, and Lady Bird Lake have fixed 100-foot CWQZ widths, measured from the official contour elevations defining each respective lake’s edge. A 2008 amendment to the CWQZ regulations for the Colorado River downstream of the Longhorn Dam changed the way that the CWQZ is measured for the river. The CWQZ is measured from the ordinary high water mark (roughly along the low-flow bank), in a manner similar to the CWQZ protection for the lakes. This change provides an effective riparian buffer zone within the CWQZ, as was the intention of the setback. (The previous measurement was from the center of the waterway, which resulted in the majority of the buffer being underwater, due to the large width of the Colorado River in comparison to the width of the CWQZ setback.)

Water quality controls are not allowed in the CWQZ except by variance, except in Urban and Suburban watersheds. Specified green stormwater controls (featuring soil and plants and not hard armoring, such as concrete walls) are allowed in the top (upslope) half of Urban and Suburban watersheds. Wet ponds and flood detention ponds are only allowed if it is demonstrated during design that they do not adversely impact channel stability by creating additional erosion or sedimentation downstream of the structure.

Potential Improvement. Significant improvements were made to stream buffer requirements in the 2013 Watershed Protection Ordinance. These changes were in direct response to recommendations in the 2001 Watershed Protection Master Plan, which emphasized the need for citywide headwaters protections. Further improvements are possible, but will likely provide a relatively modest benefit in comparison. Code language could be added to require water quality controls located in the Critical or Transition Zones to be located as close to upland areas as feasible. Vegetation goals for the stream protection zones could be established to promote native species and discourage managed turf grass or non-native species.

Water quality setbacks are recommended as buffers between golf course turf management and streams. Water quality monitoring data indicate significant differences in baseflow concentration of nitrate, ammonia, total dissolved solids, total suspended solids and turbidity concentrations associated with golf courses using treated wastewater effluent for irrigation. Stormwater runoff samples indicate that tributaries associated with a golf course site are significantly higher in nitrates, ortho-phosphorus, and lower in pH than samples from tributaries associated with residential and rural land uses (City of Austin, 1997; City of Austin, 2005).

9.4.5.8 Critical Environmental Features (CEFs) Protection

Section 25-8-1(6) of the Code defines Critical Environmental Features (CEFs) as "features that are of critical importance to the protection of environmental resources, and includes bluffs, canyon rimrocks, caves, faults and fractures, seeps, sinkholes, springs, and wetlands." Section 25-8-281 outlines required protections, which include setbacks, protection of drainage patterns to prevent degradation, exclusion of CEFs within residential lots, and restricted activities within setbacks (City Code). Figure 9.4.5-4 shows active recharge through a karst feature in Onion Creek.

Figure 9.4.5-4 Recharge feature in Onion Creek watershed

Regulations protecting Critical Environmental Features have been expanded to address void mitigation conditions in construction documents submitted in the review phase to protect sinkholes, caverns, and features encountered during the construction process that were not detected during

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the environmental assessment of site engineering. Additionally, WPD has also worked with TCEQ to adopt equivalent measure for the Edwards Rules (30 TAC 213), and has incorporated consideration and protection of CEFs into the City of Austin CIP project planning process.

9.4.5.9 Wetlands Protection

The City defines wetlands as lands that are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or land is covered by shallow water. Wetlands classification is based on technical definitions established or used by the U.S. Army Corps of Engineers. A designated wetland is a Critical Environmental Feature (see previous section). City Code requires protection for all wetlands except those within the Central Business District (Section 25-8-282). Protection includes provision of appropriate setbacks or wetland mitigation.

Wetland areas proximate to streams are critical components of systems that maintain baseflow and support aquatic life. Critical Water Quality Zone buffers also provide protection for many of these wetland areas. The 2013 Watershed Protection Ordinance extended headwaters protections to Suburban watersheds and other creeks previously without buffers, thereby increasing protections for many wetlands. Figure 9.4.5-5 shows a wetland in the Little Walnut Creek watershed.

Figure 9.4.5-5 Protected wetland in Little Walnut Creek watershed

9.4.5.10 Landscape Regulations

Landscaping can lower nutrients and toxic concentrations in waterways by enhancing infiltration and supplementing baseflow. Effective landscaping practices can also infiltrate stormwater into the soil (supplementing baseflow) and reduce leached nutrients, pesticides, and herbicides in creek flow.

City of Austin landscape regulations affect commercial, multifamily, and other development that is permitted with site plans. Requirements include street buffering, parking lot landscaping, and a minimum level of landscaping between the buildings and street. Landscape criteria in the ECM encourage the use of native, adapted, and xeriscape plants. City landscape regulations also require native landscape areas as a condition for impervious cover transfer credits, as well as maintenance of hillside vegetation on steep slopes.

A 2009 ordinance revision required at least two trees of two different species (listed in ECM Appendix F) for single-family small lots in the SF4-A zoning district, and at least three trees of two different species for single-family lots in any zoning district other than SF4-A. The City Arborist has flexibility

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to accept preservation of an existing tree on the lot in lieu of requiring a planted tree, and allows alternative compliance under limited circumstances. A second 2009 ordinance increased the landscape requirements for large parking lots.

A 2010 ordinance required that commercial stormwater runoff be directed to an area equivalent to at least 50% of required landscaped area. Supplemental irrigation is still required for newly-planted landscaping. There are a number of ways to direct stormwater to landscaping, ranging from simpler solutions like overland flow and disconnected downspouts to more sophisticated designs like rain gardens and rainwater harvesting. Landscaped areas can be—but are not required to be—designed to achieve water quality credit by integrating innovative water quality controls like rain gardens or vegetative filter strips. Undisturbed natural areas and undisturbed existing trees can also be counted toward the 50% requirement so long as no potable irrigation is installed for these areas.

Potential Improvement. As a part of the CodeNEXT Land Development Code revision process, City of Austin staff from multiple departments came together in 2015 to review the existing Landscape Code. Spurred by an increase in the number and types of projects being submitted for review, and recognizing the need to re-examine how the landscape regulations apply to different urban contexts, the group took on the task of understanding the current challenges and opportunities in order to make recommendations to the CodeNEXT team. The working group identified several key goals to improve the landscape regulations:

- Accomplishes functional objectives identified in the original intent language
- Works for all sites in differing contexts
- Practical to design and construct
- Practical to review and inspect
- Provides adequate soil volume for shade trees
- Promotes innovative stormwater management and irrigation techniques

The working group also identified solutions to offer possible paths forward, including:

- Ensure all zoning types have some landscape features incorporated into the code, especially urban core sites with little to no streetyard.
- Explore context-sensitive solutions for different urban patterns.
- Investigate the threshold to require landscaping for remodels.
- Strengthen provisions for shade trees, including soil volume requirements and incentives for preserving existing trees and other undisturbed areas.
- Require on-site infiltration of some quantity of stormwater and/or demonstration that landscapes receive stormwater or other non-potable water unless shown infeasible.
- Revise irrigation requirements to allow/encourage/require irrigation of some landscaped areas with non-potable water (including stormwater).

9.4.5.11 Tree Protection Standards

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Tree regulations protect trees in three size classes: native trees between 8-18 inches in diameter must be preserved to the extent feasible and mitigation is required when preservation is not feasible; trees 19-23 inches in diameter are protected trees and are only allowed to be removed under certain conditions; and native trees 24 inches in diameter and greater are considered "heritage" trees. For heritage trees between 24 and 29 inches in diameter, specific administrative criteria are set forth for conditions under which removal is permitted. A City board and commission variance must be requested to remove a heritage tree that does not meet administrative criteria for removal. With the exception of dead, diseased, or imminent hazard trees, removal of a heritage tree with one stem greater than 30 inches necessitates a board and commission hearing and approval. These additional protections for heritage trees were adopted by Council in 2010.

The City has taken steps in the development process to control non-native, invasive species and require replanting native trees when native trees are removed for development. Non-native, invasive trees are required to be surveyed if of regulation diameter. However, no mitigation is required for removal of these trees. The ECM also requires that a native tree species be used to satisfy mitigation requirements if a native regulation diameter tree is removed. "Native" is defined as trees native to the Texas Blackland Prairie or the Edwards Plateau ecological regions.

Figure 9.4.5-6 Tree protection fencing

Preservation of a tree is based on Code requirements that dictate allowable impacts in the critical root zone and canopy removal of the tree. For every one inch in diameter, there is a one foot radius critical root zone. For example, a 20 inch diameter Live Oak (*Quercus fusiformis*) has a 20-foot radius or 40-foot diameter critical root zone. Code requires that at least 50% of the entire critical root zone is preserved. Further, restrictions limit cut and fill within 10 feet of the center point of the tree and no impacts are allowed within five feet of the tree. Code also limits canopy removal to 25%. Mitigation is required when a native tree of regulation size is removed or if a tree is to remain, but code compliant tree preservation is not met. Figure 9.4.5-6 shows protective tree fencing. Tree protection fencing and/or other methods are required during construction activities. Mulching, fertilization, and proper root pruning is often required as part of tree care during construction.

Potential Improvement. Analysis and any subsequent modification to tree regulations will be considered in the CodeNEXT process to comprehensively revise the Land Development Code.

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9.4.5.12 Natural Channel Conveyance Requirements

The Impervious Cover Disconnection section above describes the benefits of designing development such that runoff from impervious surfaces can infiltrate back into the soil rather than be concentrated. Natural channel conveyance requirements ask that flows from impervious surfaces be directed to vegetated areas (e.g., vegetated filter strips along roads) and/or conveyance channels (e.g., grassy swales) rather than via concrete gutters and pipes. The use of curbs and gutters is restricted for streets located within the CWQZ and the WQTZ of Water Supply Rural or Water Supply Suburban watersheds. Within these watersheds, any roadway within the uplands zone may be designed without curbs and gutters. Also within these watersheds, the transportation engineer may modify minimum street right-of-way widths to satisfy stormwater drainage requirements and the general public welfare.

Code Section 25-7-61 also requires development to preserve the natural and traditional character of the land and the waterways located in 100-year floodplains to the greatest extent feasible. Preservation of natural features (soils, vegetation, grades, etc.) maximizes infiltration, pollutant removal, and overall stormwater management.

Potential Improvement. The Code requirement to preserve the natural and traditional character of land and waterways to the greatest extent feasible presents problems in implementation. One potential regulatory expansion would be to provide additional definition of "natural and traditional character." The definition might include preservation of the existing flow regime, existing and natural stream geomorphology, and the preservation of native vegetation, stream shading, and biological components.

The DCM has been revised to include conveyance of natural channels in the floodplain modification criteria. Further expanded regulations would be requirements or incentives to provide drainage through swales and encourage stream restoration design techniques. Regulations applicable to the Water Supply Suburban and Water Supply Rural watersheds could be extended throughout the City's watersheds.

9.4.6 Incentives and Enforcement

The sections below discuss aspects of City regulations related to incentives and enforcement in order to achieve the Watershed Protection Department's Flood Mitigation, Erosion Control, and Water Quality Protection missions.

9.4.6.1 Regulatory Incentives

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Regulatory incentives can include flexible implementation of regulations, fee waivers, tax abatement, access to city utilities, and streamlining the development review process. The City currently offers these incentives on a case-by-case basis.

9.4.6.2 Land Acquisitions and Conservation Easements

City of Austin regulations encouraging land acquisition or conservation easements are those that provide for a transfer of development rights to upland areas based on restricting development in sensitive areas. These regulations encourage transfer of the Critical Water Quality Zone to the City in fee simple, and the maintenance of WQTZ and upland areas in a natural and undisturbed state. City regulations also require parkland dedication as a condition of development permits.

Undeveloped areas can be preserved by either fee simple purchase of undeveloped land, or by acquisition of the development rights and establishment of a conservation easement. Figure 9.4.6-1 shows a karst feature in Watershed Protection Lands.

The 2013 Watershed Protection Ordinance (WPO) added a new transfer option that allows uplands-to-uplands transfers for each acre of land in an uplands zone located either in the 100-year floodplain or in an environmentally sensitive area (as determined by an environmental resource inventory).

Figure 9.4.6-1 Karst feature in Watershed Protection Lands

Potential Improvement. The City could consider additional regulations to facilitate the acquisition of conservation easements to preserve the existing rural character of Austin's undeveloped watershed areas. One such idea was presented in the Regional Water Quality Protection Plan for the Barton Springs Zone (BSZ) (Naismith Engineering, 2005). This plan presented a non-binding set of measures recommended for all communities located in the BSZ; the City of Austin was one of the many participants which approved the plan. A major plan element was the concept of "transfers of development rights" (TDRs). The recommended TDR system, if implemented, would allow a property in one area to increase its impervious cover above standard limits if it purchased the impervious cover rights from another tract elsewhere in the BSZ. Various restrictions and exceptions were described. The City of Austin has not adopted this system in full, but the 2007 passage of the BSZ Redevelopment Exception provided a TDR system for the subset of redevelopment properties (the SOS Ordinance requires site-by-site compliance with impervious cover limits and does not allow transfers between tracts). See also the “Redevelopment Exception Options” section below. The extension of TDRs to “greenfields” development—rather than just to redevelopment—will provoke a great deal of debate in the community. There is much disagreement as to the net positive or negative impact of allowing increased intensity and density for some sites while providing preservation of others. See “Impervious Cover Limits” section above for more discussion of this topic.

9.4.6.3 Variance Procedures

The City Code includes procedures for requesting variances from regulations. A variance can only be requested from when an application for a subdivision of land or a site development permit has been filed. Some variances can be granted administratively, but most require approval from the Planning Commission. Strict findings must be met which attempt to weigh the justification for the variance, assess whether similar variances have been granted, and evaluate the impact of the variance on the watershed. Variances are not allowed for provisions of the SOS Ordinance for water quality protections.

Potential Improvement. An improvement to the existing variance process would be to require variance applications earlier in the land development project process. The variance needs to be considered early enough in the development process so that changes can be made to the project to meet variance conditions.

9.4.6.4 Operation and Maintenance Permits for Water Quality Controls

The City currently requires operations and maintenance permits for water quality controls maintained by private entities within the Barton Springs Zone.

Potential Improvement. Continued enforcement, operation, and maintenance of source controls, structural controls, and nonstructural water quality controls may be the weakest element of Austin’s watershed protection strategy. Significant improvements might be achieved by expanding the operating permit requirement.

9.4.6.5 Environmental Resource Inventory

An environmental resource inventory (ERI)—formerly known as an environmental assessment (EA)—is required for all development located over karst aquifers, within areas draining to a karst aquifer or a reservoir, tracts with slopes greater than 15%, or tracts with Water Quality Transition or Critical Water Quality Zones. An ERI must include a hydrogeologic element, a vegetative element, and a wastewater report. With the 2013 WPO, the hydrogeologic element must provide an inventory of all recorded and unrecorded water wells, both on the site and within 150 feet of the boundary of the site.

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As recommended by the 2001 Master Plan, standards have been established for the biological and geological assessment components which set down minimum qualifications for persons conducting assessments.

Potential Improvement. The ERI process for City projects might be streamlined by requiring circulation of a project description for review prior to any budget hearing. A determination as to whether an environmental assessment is necessary could be part of this preliminary capital project review process.

9.4.6.6 Payment-in-Lieu Alternatives

The City of Austin has options for payment-in-lieu of construction for structural flood and water quality controls. In either situation, a developer can request to make a payment to the City and avoid the land, capital, and operating costs of an on-site structural control. The City has discretion as to whether to accept the payment based on a number of criteria.[2] If a payment is accepted, the funds are used to construct flood mitigation or water quality improvement projects to offset existing development impacts.

The payment-in-lieu option for flood detention is available in some watersheds as part of the Regional Stormwater Management program (RSMP). The RSMP was established in 1984 in recognition of the limited effectiveness of on-site detention ponds in many situations, but also in recognition that all new developments contribute to the increased amounts of stormwater runoff in a watershed. Participation in the RSMP is available in watersheds in and around the City that are currently developing and have potential for flooding problems as undeveloped land is converted to impervious cover. In these watersheds, the RSMP allows developers to participate in the program instead of constructing on-site controls if the proposed development will produce no identifiable adverse impact to other nearby properties due to increased runoff. The RSMP option is not available in other watersheds where regional solutions are not feasible.

Potential Improvement. Potential modifications could include a requirement to demonstrate that no increased channel erosion or localized flooding downstream would result from payment of a payment-in-lieu for water quality controls. The City could require a downstream erosion analysis as part of a water quality control payment-in-lieu application; local flooding information could be supplied by the City. If downstream impacts are judged to be unacceptable using payment-in-lieu, the application would be denied. Payment-in-lieu of water quality could also be granted for projects larger than one acre for commercial and two acres for residential subdivisions such that water quality volumes are reduced accordingly. For example, a three-acre site could pay for

[2] These criteria are enumerated in Section 9.4.4.11, Water Quality Controls.

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one acre of its development and provide on-site controls for the remaining two acres (to work around demonstrated, site-specific constraints). Another option would be to consider extending the payment-in-lieu of water quality system to one- and two-acre projects in Suburban watersheds. All of these options will require further study prior to implementation.

9.4.6.7 Application of Standards to Single Residential Lot Construction on a Platted Lot

Application of the City's development rules and ordinances is generally occurring with the review process associated with approving a subdivision plat or granting a development permit for commercial development or subdivision infrastructure. Rules and ordinances can be applied through covenants, plat map conditions, or easements. Enforcement of development requirements on individual lots, however, occurs at the time of building permit application (inside the City only), and sometimes through financial lending institutions.

Potential Improvement. The Land Development Code could be amended to prohibit single-family lot clearing until a building permit is issued within the City limits. Alternatively, where home construction is to occur simultaneously with subdivision infrastructure construction, the limits of construction for infrastructure could be expanded to include the home and driveway areas. The fiscal posting for erosion control and revegetation would be increased to include the additional area. A time limit between clearing and construction completion would be established. Either of these solutions would address erosion and sedimentation that results when cleared homesites remain vacant.

9.4.6.8 Application of Standards to Subdivision of Illegal Lots

Lots exist within the City that have never been part of a legal subdivision process. When these illegal lots come in for any type of permit, they are required to go through the subdivision process prior to issuance.

9.4.6.9 Redevelopment Exception Options

The City of Austin facilitates redevelopment of existing developed ("greyfield") areas to incentivize infill and thereby reduce urban sprawl in undeveloped "greenfield" areas. Two "Redevelopment Exceptions" are offered: one for citywide projects and a specialized option for the Barton Springs Zone. These exceptions were created to address concerns that desirable redevelopment may be impeded if it is expected to comply with the full requirements for greenfields development.

The citywide Redevelopment Exception was added to the Code in 2000. It allows an existing developed site to redevelop its existing footprint (even if over the watershed impervious cover limit) and in its existing location (e.g., even if in a stream buffer) if it provides on-site water quality controls (frequently non-existent in older developments), but it may not increase the existing level

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of impervious cover. For sites in the Drinking Water Protection Zone, the redevelopment area is limited to 25% of the site's existing impervious cover.

A Barton Springs Zone (BSZ) Redevelopment Exception was added in 2007. It allows a BSZ site to retain all of its existing impervious cover in exchange for providing (1) an on-site water quality control, and (2) off-site land mitigation (via payment into a fund or donation of land fee simple) such that the subject tract plus the off-site tract collectively provide 20% or less impervious cover. City Council approval is required in some circumstances. Additional restrictions apply to the citywide and BSZ Redevelopment Exceptions regarding traffic volumes, neighborhood plans, and existing non-compliance with other Code provisions.

9.4.6.10 Legal Enforcement

The City's process for enforcing watershed protection ordinances consists of several steps. The first step is to notify the violator of the situation. The inspection department may leave notice through three stages: verbal notice, written notice, and red tagging the project. After notice is provided to the violator, the next step in the enforcement process is for the City to file a criminal complaint in municipal court. Penalties for code violations are specified in City Code Section 25-1-462. Only where there is imminent danger to health and safety can the City receiving a temporary restraining order or injunction.

Potential Improvement. The Code related to watershed protection has been written from the perspective of code defendants rather than from a prosecutor's perspective. Several of the sections are written so that enforcement is problematic. A potential modification could include modification of Code language to allow for improved enforcement.

A potential alternative to the Municipal Court process would allow Austin Police Department officers to write a ticket for an environmental violation. Similar to a traffic ticket, such tickets for code violations would be quicker, easier, and result in increased enforcement of the City's code. Tickets cannot, however, be written for these violations without authorizing state legislation.

Section 10

10 Identifying Preferred Solutions

This section presents the protocol used to identify preferred solutions to address watershed problems.

10.1 Protocols Established

To target solutions a screening protocol, or set of procedures, is used to identify specific capital, programmatic, and regulatory solutions from the full set of potential solutions presented in Section 9 that would be appropriate or applicable for solving watershed problems. This protocol provides a framework to consider the nature and context of a given watershed problem; its potential solution types (capital, regulatory, or programmatic); the strengths, feasibility, and possible negative impacts of these solutions; and community considerations for the area in which the solution is proposed.

Solutions are measured by their effectiveness in achieving the watershed protection goals outlined in Section 2. Ideally, preferred solutions:

- Meet flood, erosion, and water quality goals and objectives;
- Maintain or improve the natural character of waterways;
- Minimize required maintenance;
- Ensure compliance with local, state, and federal regulatory requirements; and
- Foster additional beneficial uses of waterways and drainage facilities where possible.

Solutions are also assessed for their ability to implement the vision, goals, and priorities of the Imagine Austin Comprehensive Plan. As discussed in Section 9, Imagine Austin organizes the various actions needed to implement the vision and policies of the plan into eight “priority programs.” Each priority program has a lead department, cross-functional team, partners, and a work plan.

WPD helps lead the implementation teams for both the “Sustainably Manage Our Water Resources” and “Green Infrastructure” priority programs. These teams evaluate current City programs and regulations to diagnose what is working, what needs to be changed, and what needs to be explored further in order to implement the policies and actions of Imagine Austin. In addition, each City department’s Capital Improvement Program (CIP) Plan is required to address how proposed projects will help implement the priority programs of Imagine Austin. For example, the installation of rain gardens helps sustainably manage our water resources and uses green infrastructure to integrate nature into the city.

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10.2 Watershed Profiles

The 2001 Master Plan presented an individual watershed summary for each of the 17 Phase 1 watersheds. A new system is included in the present Master Plan using “Watershed Profiles.” Individual summary information by individual watershed was judged no longer feasible at this time for the 49 Phase 1 and 2 watersheds now under study. Instead, a new Appendix C was created to present Watershed Profile information for watersheds citywide for eight targeted water quality problem types. Future Master Plan updates will include more specific information on small groups of like watersheds; these summaries will also contain flood and erosion control elements. In addition to watershed classifications, the information collected for the Watershed Profiles could also be tailored to smaller geographies such as individual watersheds, neighborhood planning areas, or 10-1 Council districts.

The water quality mission was selected as the first to consider with the Watershed Profiles given its historic complexity (e.g., 27 different factors monitored by the EII alone) and the relative difficulty of implementing feasible solutions in comparison to the other missions. In addition to the Watershed Profile summaries, a Base Map was developed for each water quality problem score. The purpose of the Base Map is not only to provide a clearinghouse of related data, but also to spatially correlate potential sources and solutions with the problem scores for individual EII reaches.

In a future Master Plan update, the Watershed Profiles will be expanded to provide the following information for each watershed grouping for all missions:

- Summary of existing data and analysis, including natural features and infrastructure;
- Catalogue of existing problems, including problem scores and priorities for each mission;
- Catalogue of historic and ongoing solutions, including projects, regulations, and programs;
- Identification of potential future solutions.

10.3 Identifying Preferred Capital Solutions

10.3.1 Mission Integration and Prioritization (MIP) Team

WPD formed a Mission Integration and Prioritization (MIP) Team in 2001 to coordinate the prioritization of capital projects and facilitate integration of the erosion control, flood mitigation, and water quality protection missions into all watershed protection capital projects. The MIP Team was the first interdisciplinary team formed by WPD, and included representatives from Creek Flood, Local Flood, Erosion Control, Water Quality Protection, and Master Planning. Membership of this team has since expanded to include Field Operations, Value Engineering, Floodplain Modeling, Water Quality Monitoring, CIP coordination, and Sustainability. The objective of the MIP Team is to identify, prioritize, and integrate responsible funding plans for capital solutions to implement improvements in water quality, channel stability, and stormwater conveyance.

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Initial protocols for capital solution selection began by overlaying map layers of all mission Problem Areas to see which areas had significant overlap. From this process, four Watershed Management Areas (WMAs) were identified in Boggy, Fort Branch, Little Walnut, and West Bouldin watersheds. Watershed Management Areas were established by using a classification of creek segments into categories that were undertaken to analyze watershed problems within these areas, and develop conceptual integrated solutions. Conceptual solutions were further evaluated for feasibility and cost benefit. From this, several alternatives were considered and specific capital projects were selected for implementation, based on problem severity and availability of funding. Details of these projects can be found below.

The Fort Branch WMA Reach 6 and 7 project (5848.057[1]) included benefits for all three missions through upgrades of a low-water crossing on Fort Branch Blvd., with a new span bridge, channel improvements for erosion and water quality using natural channel design approach, and upgrades for two storm drain systems. In June of 2015, this project was complete and in its final warranty period.

The West Bouldin Integrated Water Quality Project (5282.008) evaluated retrofits and stream corridor restoration opportunities. It resulted in the construction of a series of water quality controls in the upper watershed, completed in 2012.

The Boggy Creek study (6039.031) resulted in a number of projects for all missions, including three riparian restoration projects to improve water quality (6660.033, 6660.052, 6660.059). Two of these restoration projects are in the construction phase as of June 2015, and one is in the post-construction phase. Additional projects resulting from this study include creek restoration projects to improve both water quality and to protect the creek against the threat of erosion (Boggy Creek Cherrywood - 5848.058 in post construction as of June 2015, and Boggy Creek Reach 8-5848.059, located in Rosewood Park, in construction as of June 2015). Two flood mitigation projects have been identified to address flooding concerns for this area (5754.050 and 5754.079), but have been placed on hold pending available funding. These project areas correspond to the 9th ranked Priority Problem Area.

The Little Walnut Creek study (6039.034) proposed a flood improvement project (5754.086) that will include a creek bypass system under Mearns Meadow Blvd and upgrades to the culverts at Quail Valley. This project was in design as of August 2016.

While the WMA capital selection protocol successfully identified high priority project needs, its application was limited to those areas that had a significant overlap of different, high ranking watershed mission problems. The 2001 Master Plan recommended that protocols be developed to identify a prioritization and integration process to cost effectively address watershed problems of

[1] These codes refer to Project Numbers in the City of Austin's eCAPRIS project tracking system, available for public viewing on the web.

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multiple missions. In response to this recommendation, in 2005 WPD established a formal mission integration process in an effort to further improve staff coordination and project design and to maximize project cost benefits. This process, administered and monitored by the MIP Team, is ongoing and includes a yearly evaluation of its success in identifying continual opportunities for improvement.

The Mission-Integration and Prioritization (MIP) process seeks to identify and implement capital projects that perform the following primary functions:

1. Maximize opportunities to advance individual mission objectives;
2. Seek opportunities to attain common goals; and
3. Minimize negative impacts to all missions.

Because current watershed conditions often fall short of watershed protection goals, WPD seeks opportunities to address multiple watershed problems and enhance project benefits. Projects usually originate from a single mission's Top 20 Priority Problem Areas and are sponsored by that mission. Through the MIP process, opportunities are sought to address as many watershed goals in the project area as possible. For example, an erosion control project would try to resolve nearby flood problems, but would especially ensure that it did not worsen or create new problems. MIP projects also seek to meet WPD's common goals (see Table 2.4-1), such as "maximize the use of waterways and drainage facilities for public recreation," and many others. MIP projects also seek to directly support the Imagine Austin Comprehensive Plan, including specific action items identified in Neighborhood, Corridor, Transit-Oriented Development (TOD), and other "small area" plans.

As part of the yearly capital budget planning process, updated mission problem scores and Top 20 ranked Problem Areas are developed for each mission (This process is described in detail in Sections 4 to 7). These Problem Areas are evaluated by each mission to identify the Top 20 "Priority Problem Areas," submitted for the annual MIP integration and CIP project funding appropriations processes. This evaluation varies between missions and is explained in more detail in Sections 10.3.2 – 10.3.5 below. Tables 10.3-1 through 10.3-5 present the Top 20 Problem Areas and corresponding Priority Problem Areas identified by each mission. These Top 20 Priority Problem Areas are further evaluated by WPD for capital solution feasibility. Each mission completes a feasibility analysis to determine the range of capital solutions that could conceptually address the problem, and a rough cost estimate is provided based on construction costs of similar capital projects constructed by the City.

Figures 10.3-1 through 10.3-5 present maps showing the resulting Top 20 Priority Problem Areas for each mission: Creek Flood Structures, Creek Flood Road Crossings, Local Flood Problem Areas, Erosion Geomorphic Reaches, and Water Quality EII Reaches. Each is shown in context with other areas having lower problem scores (ranging from Very Low or Low to Very High). Each represents the data available at the time the annual WPD CIP appropriation process begins. Scores are updated

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yearly and subsequent information available later and/or improvements to evaluation methodologies may change the relative rankings of these areas. Figures 10.3-6 and 10.3-7 show the Top 20 Priority Problem Areas for all missions.

Once a Priority Problem Area is determined to have a feasible solution, it is reviewed by the Mission Integration and Prioritization (MIP) Team to determine the integration potential of the project based on the process described below. This review ultimately results in the identification of capital projects that are included in the five-year CIP appropriation plan that is provided to the City's Budget Office as part of the annual budget approval process. Tables 10.3-1 through 10.3-5 present the identified capital projects included in the five-year appropriation plan based on this process and the corresponding Priority Problem Areas.

Not every Priority Problem Area will result in a capital project moving forward through the appropriation process. Some Priority Problem Areas may be determined to not have a feasible solution, or, more specifically, the cost may be determined to be too high for the WPD to fund though its traditional funding sources. These Problem Areas may be "set aside" until another funding source is available, such as general obligation bonds, grants, or some other type or combination of funding. This is explained more thoroughly in Sections 10.3.2 through 10.3.5. Tables 10.3-1 through 10.3-5 present Problem Areas, Priority Problem Areas (or reasons why a project is not currently feasible), and capital projects identified in the 5-year Plan for Fiscal Year 2014. These 2014 figures are presented as a one-time snapshot of this process. This information changes as new problems and solutions are studied and will be updated on an annual basis to supplement this Master Plan.

Lower Shoal Creek is an example of a high priority creek flood Problem Area where the estimated cost will likely exceed what is conventionally feasible for WPD to fund through the Drainage Utility Fund. This high priority problem was originally studied through a partnership between the City and the US Army Corps of Engineers in the early 1990s. That study evaluated several different flood control options and identified a bypass tunnel as the most cost-effective solution. Due to the project solutions not satisfying the federal involvement model and due to the costs exceeding the City's funding capacity, no action was taken to implement this solution. As 25 years have passed since the completion of that study, the department is preparing to conduct a new feasibility study to reevaluate the mitigation options for this part of the watershed. The City will work to identify grants, federal funding, other forms of City funding (such as future bonds), as well as potential partnerships that could help contribute toward the cost to address this project.

Other considerations impact how projects move forward for appropriation. As projects are considered for funding, there are some instances where projects resulting from one integrated study may be

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recommended for individual implementation by the sponsor mission, as was done with the Boggy WMA project discussed above. This is often the case when a given area has multiple mission problems, and project costs are high. With the limited capital funding available, project implementation may need to be phased over multiple years. Even when projects are implemented individually, there are multiple benefits resulting from an integrated project scope. Cost savings as well as better informed decisions for alternative selection and project design have been noted, due to a broader base of information available to inform decision-making for the project area.

Once a mission brings a potential CIP project forward for funding, the MIP process relies heavily on geographic data evaluation and begins by identifying all watershed problems within the vicinity of the proposed project, called a “Zone of Influence” (ZOI). The size of this geographic area is defined by the type of project proposed based on a technical guidance criteria. The missions identify all the related Master Plan goals from Table 2.4-1 that could potentially be addressed by the proposed project. The MIP and Value Engineering (VE) Teams (described in Section 10.6) then conduct a group field visit to walk the area identified in the ZOI, discuss watershed problems, verify field conditions, and consider all potential solutions. Each mission has an opportunity to identify which watershed problems they would like to see included for analysis in the scope of study for the potential project. The Project Sponsor, with assistance from the MIP and VE Teams, then develops a scope of work identifying both the watershed problems and potential solutions that should be evaluated in the preliminary engineering report. Upon completion of the report, the teams review the findings and discuss the proposed project alternatives. Using the rough cost estimate that is provided, a decision can then be made as to which alternative should be pursued, and which watershed problems are feasible to address with this project. The WPD Executive Team weighs in on the project alternative selection as appropriate.

Table 10.3-1 Top-Scoring Creek Flood Structure Problem Areas and Corresponding Mission-Identified Top 20 Priority Problem Areas and Capital Solutions (Oct. 2015)

Prob. Score Rank	Problem Area Name (Cluster Name)	Watershed	Prob. Score	Top 20 Priority Problem Area (Mission-Identified for MIP Process)	Top 20 Priority Rank*	Capital Project Identified in 5-Year Plan (2015)
1	Lower Onion Creek Buyouts	Onion	100.00	Lower Onion Creek Buyouts	1	Onion Creek - Buyouts in Conjunction with the U.S. Army Corps of Engineers
2	Lower Shoal Creek	Shoal	46.15	Lower Shoal Creek	2	Shoal Creek - Lower Shoal Creek Flood Hazard Mitigation
3	Cherry Creek to S Congress Ave	Williamson	43.67	Williamson - Cherry Creek to S. Congress Ave	3	Williamson Creek - Williamson Creek Flood Hazard Mitigation and Ecosystem Restoration Corps
4	Metropolis Dr at US 183	Carson	23.45	Carson - Metropolis Dr at US 183	4	Carson Creek Flood Mitigation
5	Pinehurst Drive Subdivision & Wild Dunes	Onion	10.31	Onion - Pinehurst Dr Subdivision & WIld Dunes	5	Onion Creek - Pinehurst Drive Subdivision
6	Waller Creek Tunnel	Waller	8.47	Waller Creek Tunnel (12th St to Lady Bird Lake)	6	Waller Creek Tunnel
7	Bastrop Hwy and Patton Ave	Carson	7.48	Carson - Bastrop Hwy and Patton Ave	7	Carson Creek Flood Mitigation
8	Shoal Creek at Hancock Tributary	Shoal	5.61	Shoal Creek at Hancock Tributary	8	Shoal Creek - Brentwood Drainage Improvements
9	Carson Creek at Dalton Lane	Carson	4.42	Carson Creek at Dalton Lane	9	Carson Creek Flood Mitigation
10	February Dr and River Oaks Trail	Walnut	3.91	Walnut Creek - February Dr and River Oaks Trail	10	Walnut Creek - Flood Mitigation for February Dr Homes
11	Shelton Road at Delwau Lane	Boggy	3.85	Boggy Creek - Shelton Rd at Delwau Ln	11	
12	Metric Blvd to Rutland Dr	Little Walnut	3.48	Little Walnut - Metric to Rutland	12	Little Walnut Creek - Creek Hazard Reduction from Metric to Rutland
13	Barton Springs Rd at West Bouldin	West Bouldin	3.42	West Bouldin - Barton Springs at West Bouldin	13	
14	Walnut at FM 969	Walnut	3.41	Walnut at FM 969	14	
15	E 38 1/2 St to E MLK Blvd	Boggy	3.16	Boggy - E 38 1/2 St to E MLK Blvd	15	
16	Upper Little Walnut at Quail Cove	Little Walnut	2.83	Upper Little Walnut at Quail Cove	16	
17	Berkman Dr to Waterbrook Dr	Fort Branch	2.81	Fort Branch between Berkman & Waterbrook	17	
18	Walnut at US 183	Walnut	2.79	*[Commercial]*	-	
19	Walnut at Waters Park Rd	Walnut	2.44	*[Commercial]*	-	
20	Shoal Creek Blvd & 49th St	Shoal	1.78	Shoal Creek at Shoal Creek Blvd and 49th St	18	
21	Speedway & 45th St (from 47th to 44th St)	Waller	1.78	Waller - Speedway & 45th St (47th to 44th St)	19	
22	University of Texas at Austin	Waller	1.54	*[Outside COA Jurisdiction]*	-	
23	Walnut at Waters Park	Walnut	1.48	*[No improvements in TCAD]*	-	
24	Thompson Lane Mobile Homes	Carson	1.37	Carson - Thompson Ln Mobile Homes	20	Carson Creek Flood Mitigation

** Top 20 Priority Rank corresponds to map label in Figure 10.3-6 (Top 20 Priority Problem Areas: All Missions)*

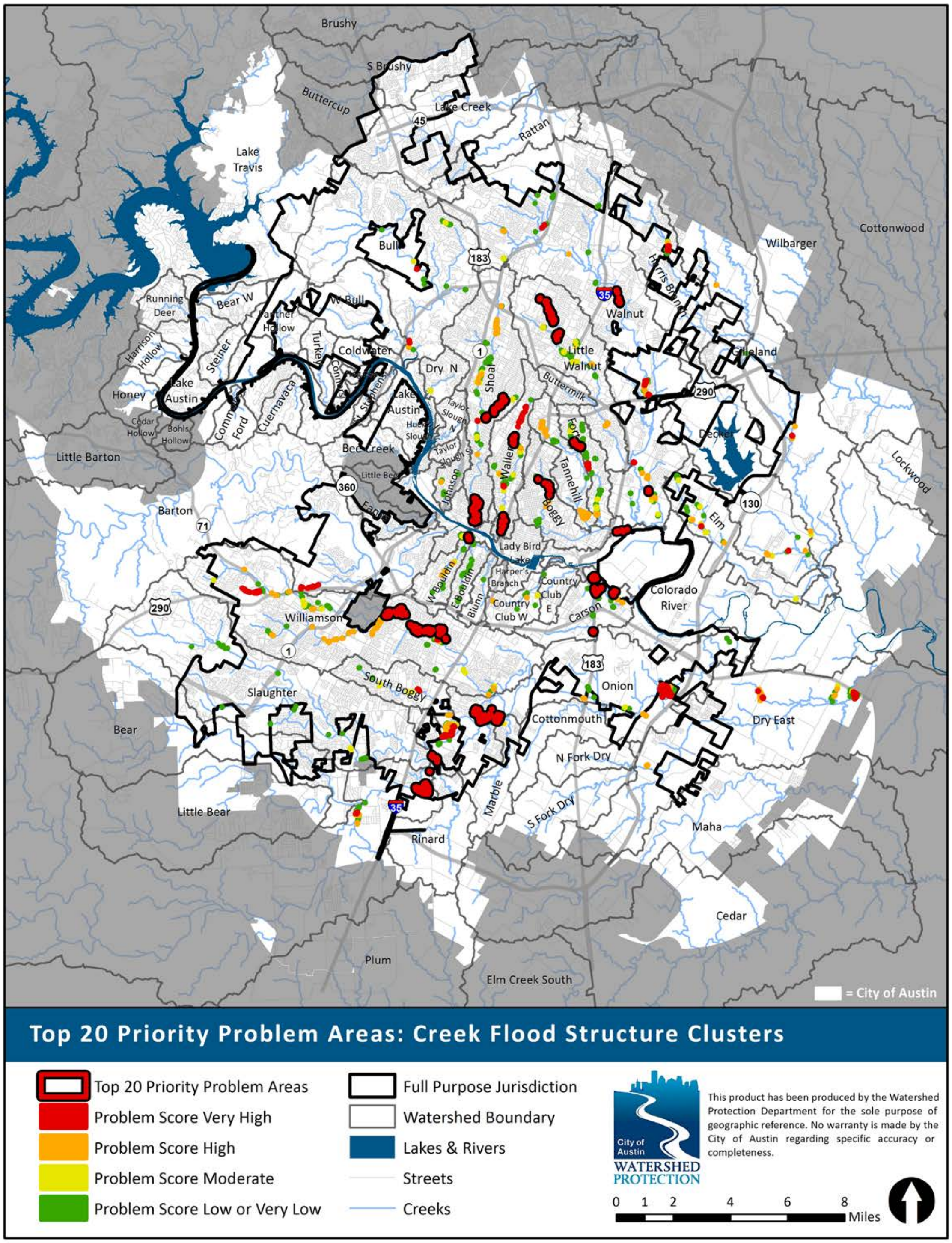

Figure 10.3-1 Top 20 Priority Problem Areas: Creek Flood Structure Clusters (October 2015)

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Table 10.3-2 Top-Scoring Creek Flood Street Crossing Problem Areas and Corresponding Mission-Identified Top 20 Priority Problem Areas and Capital Solutions (Oct. 2015)

Prob. Score Rank	Problem Area Name (Street Name)	Watershed	Prob. Score	Top 20 Priority Problem Area (Mission-Identified for MIP Process)	Top 20 Priority Rank*	Capital Project Identified in 5-Year Plan (2015)
1	Old Spicewood Springs Rd	Bull	100.00	Old Spicewood Springs Rd at 360 (3 crossings)	1	[Bull Creek - Old Spicewood Springs 3 Crossings; In-house feasibility study underway]
2	Mount Bonnell Rd	Dry Creek North	96.69	*[Assessment of potential overestimation of Dry Creek North hydrologic model underway]*	-	
3	W 9th St	Shoal	83.27	W 9th St, W 10th St east of N Lamar Blvd	2	Shoal Creek - Lower Shoal Creek Flood Hazard Mitigation
4	Old San Antonio Rd	Slaughter	72.89	Old San Antonio Rd west of S IH 35	3	[Slaughter Creek - Old San Antonio Rd Low Water Crossing Upgrade; Underway]
5	Jimmy Clay Dr	Williamson	66.89	*[Private drive serves golf course, low traffic]*	-	
6	Old Spicewood Springs Rd	Bull	55.67	Old Spicewood Springs Rd at 360 (3 crossings)	1	[Bull Creek - Old Spicewood Springs 3 Crossings; In-house feasibility study underway]
7	Delwau Ln	Boggy	54.22	Delwau Ln east of Ed Bluestein Blvd	4	
8	Waters Park Rd	Walnut	53.88	Waters Park Rd, Adelphi Rd, ONeal Ln south of Parmer Ln	5	
9	Wasson Rd	Williamson	52.70	Wasson Rd east of S Congress Ave	6	
10	Lakewood Dr	Bull	50.95	*[Project completed in 2010 - crossing upgraded to pass 2-year storm event]*	-	*[Bull Creek-Lakewood Dr. Low Water Crossing Improvements; Completed]*
11	Old Spicewood Springs Rd	Bull	49.09	Old Spicewood Springs Rd at 360 (3 crossings)	1	[Bull Creek - Old Spicewood Springs 3 Roadway Crossings; In-house feasibility study underway]
12	W 10th St	Shoal	48.03	W 9th St, W 10th St east of N Lamar Blvd	2	Shoal Creek - Lower Shoal Creek Flood Hazard Mitigation
13	Old Bee Caves Rd	Williamson	47.68	Old Bee Caves Rd north of W US 290 Hwy east W SH 71	7	
14	Cameron Rd	Harris Branch	47.02	Cameron Rd south of E Parmer Ln	8	
15	McNeil Dr	Walnut	41.64	McNeil Dr east of Mopac Expy	9	Walnut Creek - McNeil Dr Crossing Upgrade
16	W Monroe St	East Bouldin	40.76	W Monroe St east of S 1st St	10	East Bouldin Creek - W Monroe St Roadway Crossing Upgrade
-	River Hills Rd	Cuernavaca	-	River Hills Rd south of N Cuernavaca Dr**	11	[Cuernavaca Creek - River Hills Road Flood Improvements; Underway]
17	Nuckols Crossing Rd	Williamson	32.69	Nuckols Crossing Rd north of E Stassney Ln	12	Williamson Creek - Nuckols Crossing Flood Improvements
18	N Capital of Texas Highway	Bull	32.68	*[TxDOT Jurisdiction]*	-	
19	Shoal Creek Blvd	Shoal	31.48	Shoal Creek Blvd at N Lamar Blvd	13	

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Table 10.3-2 Continued

Prob. Score Rank	Problem Area Name (Street Name)	Watershed	Prob. Score	Top 20 Priority Problem Area (Mission-Identified for MIP Process)	Top 20 Priority Rank*	Capital Project Identified in 5-Year Plan (2015)
20	Fiskville Cemetery Rd	Little Walnut	31.18	*[Private drive]*	-	
21	Del Robles	Walnut	31.16	Del Robles Dr west of N Mopac Expy, south of McNeil Dr	14	
22	Waters Park Rd	Walnut	29.93	Waters Park Rd, Adelphi Rd, ONeal Ln south of Parmer Ln	5	
23	Posten Ln	Carson	29.66	*[Structural solution completed]*	-	
24	David Moore Dr	Slaughter	29.40	David Moore Dr south of W Slaughter Ln	15	*[Slaughter Creek - David Moore Dr Creek Crossing Improvements; Completed]*
25	Adelphi Ln	Walnut	28.51	Waters Park Rd, Adelphi Rd, ONeal Ln south of Parmer Ln	5	
26	Fincher Rd	Onion	27.90	*[ABIA road]*	-	
27	Joe Tanner Ln	Williamson	27.73	Joe Tanner Ln south of W US 290 Hwy	16	
28	ONeal Ln	Walnut	27.50	Waters Park Rd, Adelphi Rd, ONeal Ln south of Parmer Ln	5	
29	Escarpment Blvd	Slaughter	25.56	*[Currently undeveloped]*	-	
30	Highland Pass	Dry North	24.31	Highland Pass north of FM 2222 Rd	18	
31	W US Hwy 290	Williamson	23.79	*[TxDOT Jurisdiction]*	-	
32	W 32nd St	Waller	23.38	W 32nd St east of Guadalupe St	19	
33	Wheeler St	Waller	22.91	Wheeler St east of Guadalupe St	20	
34	Colton Bluff Springs Rd	Marble	21.35	Colton Bluff Springs Rd	17	

** Top 20 Priority Rank corresponds to map label in Figure 10.3-6 (Top 20 Priority Problem Areas: All Missions)*

*** Problem identified using Flood Early Warning System guage data, Cuernavaca watershed not currently included as a modeled watershed in the Master Plan.*

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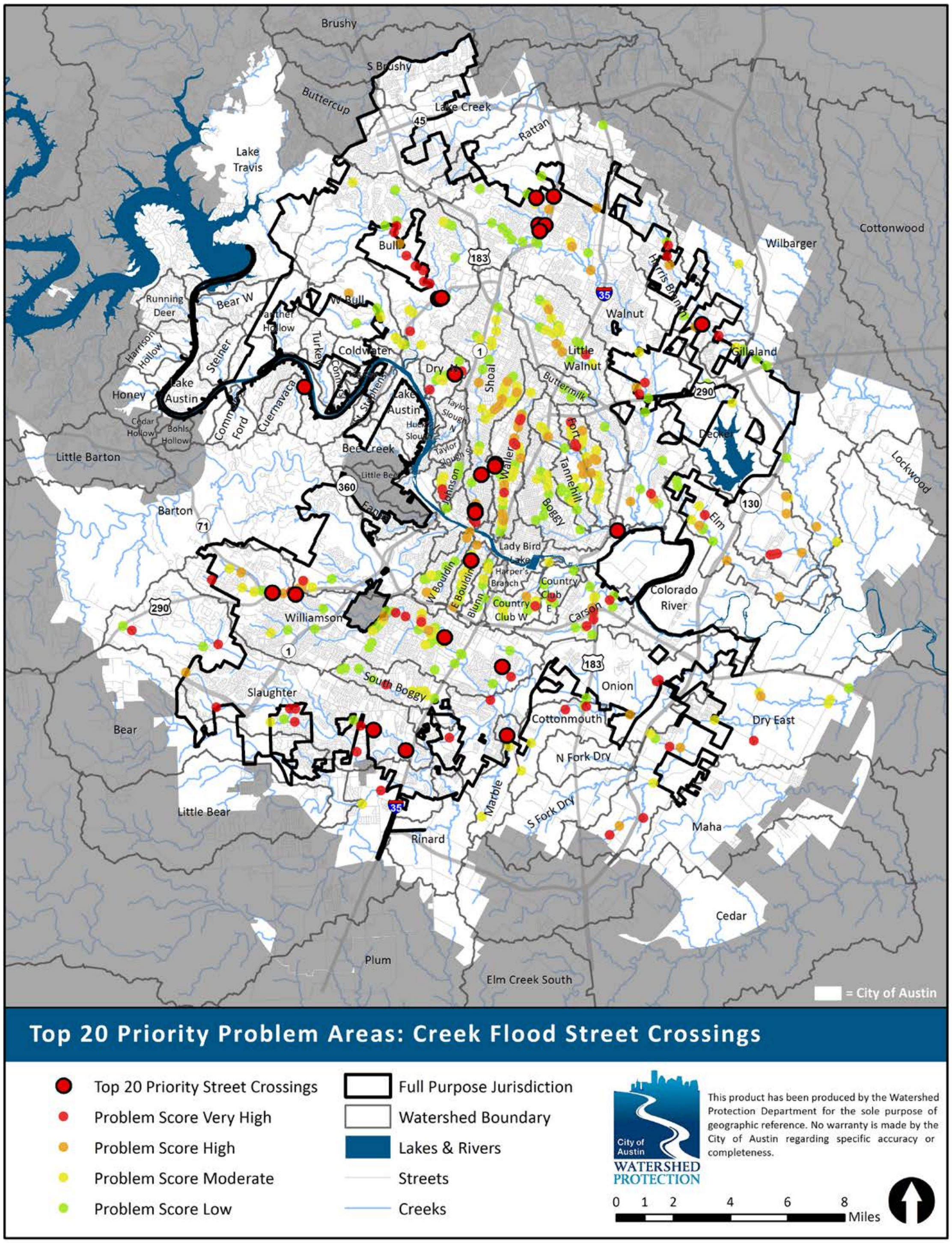

Figure 10.3-2 Top 20 Priority Problem Areas: Creek Flood Street Crossings (October 2015)

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Table 10.3-3 Top-Scoring Local Flood Problem Areas and Corresponding Mission-Identified Top 20 Priority Problem Areas and Capital Solutions (Oct. 2015)

Prob. Score Rank	Problem Area Name	Watershed	Building Complaints	Top 20 Priority Problem Area (Mission-Identified for MIP Process)	Top 20 Priority Rank*	Capital Project Identified in 5-Year Plan (2015)
1	Oak Acres	Barton	49	Oak Acres	1	Barton Creek - Oak Acres Storm Drain Improvements
2	Brentwood St	Shoal	31	Brentwood St	2	Shoal Creek - Brentwood Drainage Improvements
3	West Cow Path	Walnut	15	West Cow Path	3	Walnut Creek - West Cow Path and Whispering Valley Drainage Improvements
4	Guadalupe St	Waller	15	Guadalupe St	4	Waller Creek - Guadalupe St Storm Drain Improvements
5	Warren St	Taylor Slough S	14	Warren St	6	Taylor Slough S - Warren St Storm Drain Improvements
6	Annie St	East Bouldin	13	Annie St	5	East Bouldin Creek - Annie St Storm Drain Improvements
7	January Dr	Walnut	13	January Dr	8	Walnut Creek - January Dr Storm Drain Improvements
8	Briar Hill Dr	Lady Bird Lake	11	Briar Hill Dr	7	Lady Bird Lake - Briar Hill Dr Storm Drain Improvements
9	Madison Ave	Shoal	10	Madison Ave	9	Shoal Creek - Brentwood Drainage Improvements
10	Oakmont Blvd	Johnson	10	Oakmont Blvd	10	Johnson Creek - Oakmont Blvd Stormdrain Improvements
11	Oak Knoll Dr	Walnut	10	Oak Knoll Dr	11	Walnut Creek - Oak Knoll Drainage Improvements
12	Hollywood Ave	Boggy	9	Hollywood Ave/Group 21	12	*[Coordinated project with AW on hold until AW funding becomes available]*
13	Hancock Dr	Taylor Slough N	9	Hancock Dr	13	Taylor Slough N - Hancock Dr Storm Drain Improvements
14	North Acres	Walnut	9	North Acres	15	Walnut Creek - North Acres Storm Drain Improvements
15	Bullard Dr	Shoal	9	Bullard Dr	14	
16	Oriole Dr	Little Walnut	9	Oriole Dr	16	
17	Del Curto Rd	West Bouldin	8	Del Curto Rd	17	West Bouldin Creek - Del Curto Storm Drain Improvements
18	Stamford Ln	Johnson	8	Stamford Ln	18	
19	Jamestown Dr	LIttle Walnut	7	Jamestown Dr	19	
20	Natrona Dr	Walnut	7	Natrona Dr	20	

** Top 20 Priority Rank corresponds to map label in Figure 10.3-6 (Top 20 Priority Problem Areas: All Missions)*

Please note: Local Flood problem score data is complaint-based and therefore changes frequently due to the variable location of storm events and resulting flood impacts each year. The Local Flood mission currently lacks the resources needed to develop a model-based prioritization methodology. In the near future, the mission plans to integrate 2-D modeling results into the highest-scoring identified problem area scores. Over time, and as additional resources become available, the Local Flood mission will produce citywide engineering models of the secondary drainage system to utilize in their prioritization methodology. These methodology enhancements will incorporate both frequency and severity of flooding, in addition to type of resource threatened.

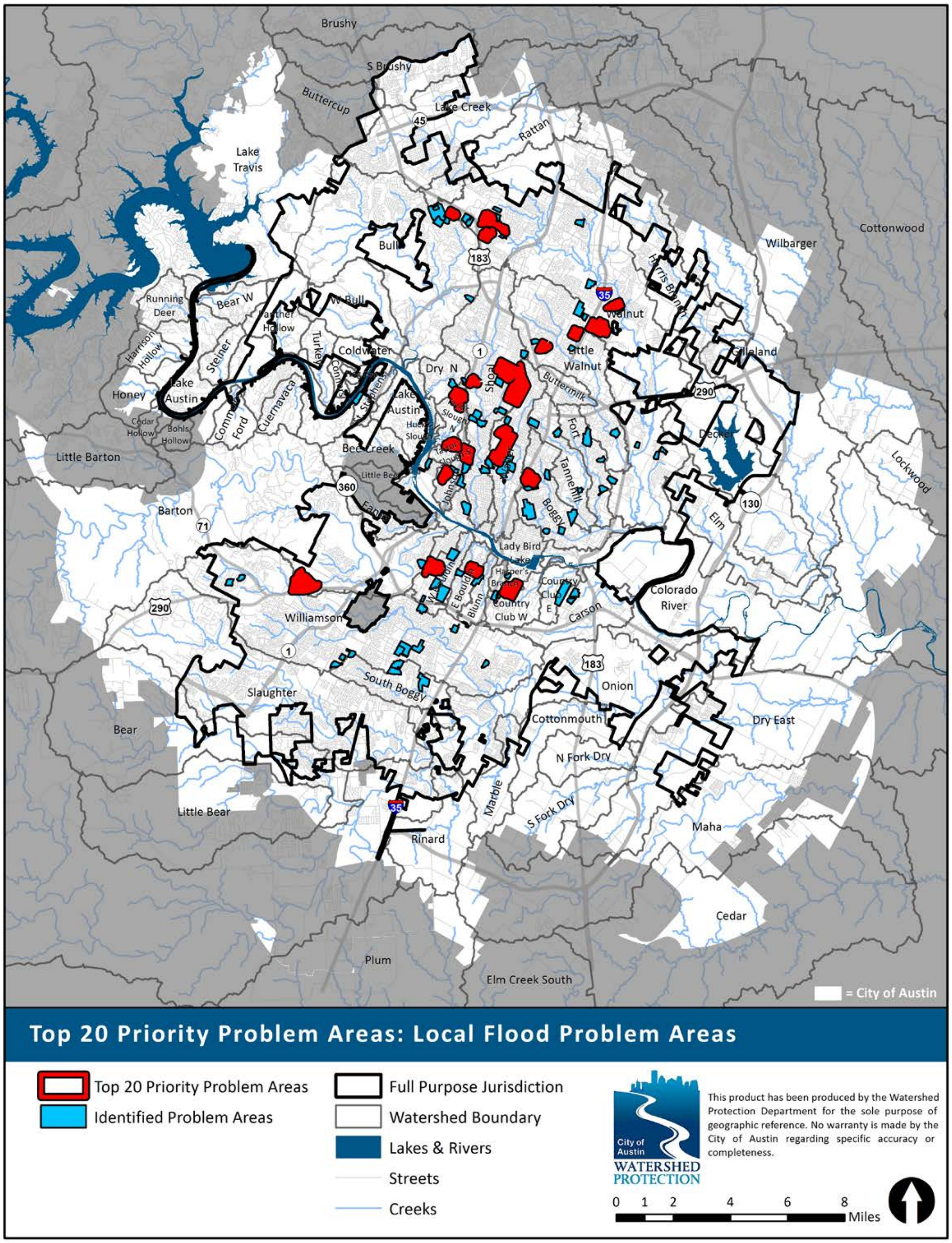

Figure 10.3-3 Top 20 Priority Problem Areas: Local Flood Problem Areas (October 2015)

Table 10.3-4 Top-Scoring Erosion Control Problem Areas and Corresponding Mission-Identified Top 20 Priority Problem Areas and Capital Solutions (Oct. 2015)

Prob. Score Rank	Problem Area Name (Reach Name) and Location	Watershed	Prob. Score	Top 20 Priority Problem Area (Mission-Identified for MIP Process)	Top 20 Priority Rank*	Capital Project Identified in 5-Year Plan (2015)
1	WLR-1 (Along Waller Creek from Confluence north to E 5th St)	Waller	100.00	Confluence north to E 5th St	1	[Waller Creek District - Creek and Trail Improvements; Funded, construction to follow Waller Creek Tunnel Improvements]
2	SHL-4 (Pease Park along Shoal Creek from MLK Blvd north to W 25th St)	Shoal	36.29	Pease Park from MLK Blvd to W 25th St	2	[Shoal Creek Restoration - 15th to 28th Streets; Underway]
3	LWA-JMA-1 (Along Little Walnut Creek from Thurmund St north to Payton Gin Rd)	Little Walnut	33.04	Jamestown Tributary from Thurmond St to Payton Gin Rd	3	Little Walnut Creek - Jamestown Tributary Channel Rehabilitation
4	SHL-3 (Pease Park along Shoal Creek from W 4th St to MLK Blvd)	Shoal	32.21	Pease Park from W 4th St to MLK Jr Blvd	4	Lower Shoal Creek - 5th to Lady Bird Lake Stream Restoration
5	WLN-WEL-2 (Along Wells Branch Creek tributary from W Parmer Ln to Walnut Creek Park Rd)	Walnut	31.20	W Parmer Ln to Walnut Creek Park Rd	5	*Wells Branch - Willow Bend Stream Rehabilitation*
6	BLU-1 (Along Blunn Creek from Little Stacy Park north to Confluence)	Blunn	30.82	Little Stacy Park to Confluence	6	*[In-house solution underway]*
7	SHL-HAN-GVR-2 (Along the Hancock Branch of Shoal Creek from Romeria Dr north to Ruth Ave and Grover Ave)	Shoal	30.43	Grover Tributary along Grover Ave	7	*Shoal Creek - Brentwood Drainage Improvements*
8	BOG-1 (Along Boggy Creek from US Hwy 183 to the confluence with the Colorado River)	Boggy	29.19	US 183 Hwy to Confluence	8	*Boggy Creek - Downstream US Hwy 183*
9	WBO-2 (Along West Bouldin Creek from Jewell St south to W Johanna St)	West Bouldin	29.04	Jewell St to W Johanna St	9	*[In-house solution underway]*
10	LWA-3 (Little Walnut Creek from Dottie Jordan Park at Loyola Ln to Manor Rd)	Little Walnut	28.33	Loyola Ln to Manor Rd	10	*[In-house solution underway]*
11	BMK-1 (Along Buttermilk Creek from US 290 northeast to near E Anderson Ln between Cameron Rd and Blessing Ave)	Buttermilk	27.97	US 290 to E Anderson Ln	11	[Buttermilk Creek - Lower Buttermilk Creek Bank Stabilization; Underway]
12	BOG-5 (Rosewood Park along Boggy Creek from E 9th St north to near E 16th St)	Boggy	26.51	Rosewood Park	12	[Boggy Creek Greenbelt -Reach B8 Stream Restoration; Completed]
13	WMS-BCR-1 (Along the Bitter Creek tributary of Williamson Creek from Branchwood Dr to Williamson Creek East Greenbelt)	Williamson	26.26	Bitter Creek Tributary	13	*[Williamson Creek - Bitter Tributary Channel Rehabilitation, Underway]*
14	SHL-5 (Pease Park along Shoal Creek from W 25th St north to W 29th St)	Shoal	24.20	Pease Park from W 25th St to W 29th St	14	[Shoal Creek Restoration - 15th to 28th Streets; Underway]

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Table 10.3-4 Continued

Prob. Score Rank	Problem Area Name (Reach Name) and Location	Watershed	Prob. Score	Top 20 Priority Problem Area (Mission-Identified for MIP Process)	Top 20 Priority Rank*	Capital Project Identified in 5-Year Plan (2015)
15	WLR-4 (Eastwoods Park along Waller Creek from Dean Keeton St north to E 45th St)	Waller	24.18	E 24th St to Avenue G	15	[Waller Creek - Eastwoods Park Stream Restoration; Underway]
16	WMS-RIC-1 (Along Richmond tributary of Williamson Creek from Redd St to Williamson Creek near S 1st St)	Williamson	21.51	Richmond Tributary	16	[Williamson Creek - Richmond Tributary Rehabilitation; Underway]
17	EBO-4C (Along East Bouldin Creek from W Oltorf St through Gillis Park to Cumberland Rd)	East Bouldin	19.55	Cumberland Rd to W Oltorf St	17	[AWU & ESD project underway]
18	SHL-HAN-3 (Along the Hancock Branch of Shoal Creek along Arroyo Seco from W North Loop Blvd north to W St Johns Ave)	Shoal	18.58	Hancock Branch along Arroyo Seco	18	Shoal Creek - Brentwood Drainage Improvements
19	TAN-7 (Along Tannehill Branch from west of Berkman Dr. to Cameron Rd)	Tannehill	18.34	West of Berkman Dr to Cameron Rd	19	*[In-house solution underway]*
20	EBO-1D (Along East Bouldin Creek from south of Barton Springs Rd south to Columbus St)	East Bouldin	16.83	Columbus St to By-Pass Structure west of S 1st St	20	*[In-house solution underway]*

** Top 20 Priority Rank corresponds to map label in Figure 10.3-6 (Top 20 Priority Problem Areas: All Missions)*

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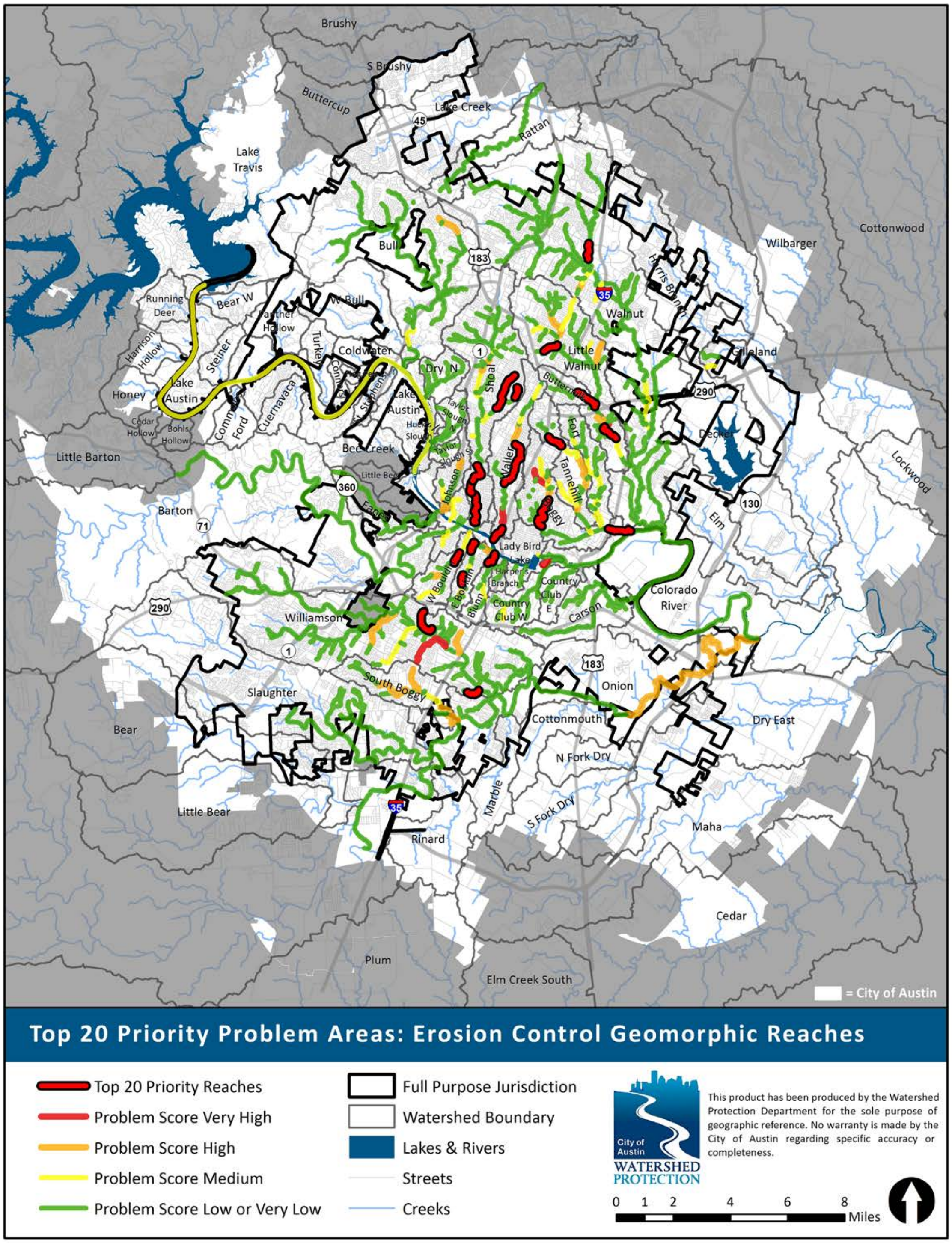

Figure 10.3-4 Top 20 Priority Problem Areas: Erosion Control Geomorphic Reaches (October 2015)

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Table 10.3-5 Top-Scoring Water Quality Problem Areas and Corresponding Mission-Identified Top 20 Priority Problem Areas and Capital Solutions (Oct. 2015)

Prob. Score Rank	Problem Area Name (EII Reach)	Watershed	Prob. Score	Top 20 Priority Problem Area (Mission-Identified for MIP Process)	Top 20 Priority Rank*	Capital Project Identified in 5-Year Plan (2015)
1	Waller Creek, EII Reach 1 (WLR1)	Waller	100	Waller Creek, EII Reach 1 (WLR1)	1	[Waller Creek District - Water Quality Retrofit; Underway]
2	Harpers Branch, EII Reach 1 (HRP1)	Harpers Branch	99	Harpers Branch, EII Reach 1 (HRP1)	2	
3	Buttermilk Branch, EII Reach 3 (BMK3)	Buttermilk	97	Buttermilk Branch, EII Reach 3 (BMK3)	3	Buttermilk EII Reach Water Quality Projects
4	Cottonmouth Creek, EII Reach 1 (CTM1)	Cottonmouth	94	Cottonmouth Creek, EII Reach 1 (CTM1)	4	
4	Buttermilk Branch, EII Reach 1 (BMK1)	Buttermilk	94	Buttermilk Branch, EII Reach 1 (BMK1)	5	Buttermilk EII Reach Water Quality Projects
4	Buttermilk Branch, EII Reach 2 (BMK2)	Buttermilk	94	Buttermilk Branch, EII Reach 2 (BMK2)	6	Buttermilk EII Reach Water Quality Projects
7	Waller Creek, EII Reach 3 (WLR3)	Waller	90	Waller Creek, EII Reach 3 (WLR3)	7	
7	Shoal Creek, EII Reach 2 (SHL2)	Shoal	90	Shoal Creek, EII Reach 2 (SHL2)	8	[Shoal Creek Restoration - 15th to 28th Streets, Underway]
9	Rinard Creek, EII Reach 3 (RIN3)	Rinard	88	Rinard Creek, EII Reach 3 (RIN3)	9	
10	Marble Creek, EII Reach 2 (MAR2)	Marble	87	Marble Creek, EII Reach 2 (MAR2)	10	
11	Lake Creek, EII Reach 3 (LKC3)	Lake	86	Lake Creek, EII Reach 3 (LKC3)	11	
11	Dry Creek North, EII Reach 2 (DRN2)	Dry North	86	Dry Creek North, EII Reach 2 (DRN2)	12	
11	North Fork Dry Creek, EII Reach 1 (NFD1)	North Fork Dry	86	North Fork Dry Creek, EII Reach 1 (NFD1)	13	
11	Waller Creek, EII Reach 2 (WLR2)	Waller	86	Waller Creek, EII Reach 2	14	
15	East Bouldin Creek, EII Reach 2 (EBO2)	East Bouldin	84	East Bouldin Creek, EII Reach 2 (EBO2)	15	
15	Tannehill Branch, EII Reach 3 (TAN3)	Tannehill	84	Tannehill Branch, EII Reach 3 (TAN3)	16	
17	East Bouldin Creek, EII Reach 1 (EBO1)	East Bouldin	81	East Bouldin Creek, EII Reach 1 (EBO1)	17	[East Bouldin Creek - One Texas Center Water Quality Retrofit; Phase 1 Completed]
18	Dry Creek East, EII Reach 1 (DRE1)	Dry East	80	Dry Creek East, EII Reach 1 (DRE1)	18	
18	Johnson Creek, EII Reach 1 (JOH1)	Johnson	80	Johnson Creek, EII Reach 1 (JOH1)	19	Johnson Creek Regional Water Quality Retrofits
20	Taylor Slough South, EII Reach 1 (TYS1)	Taylor Slough S	79	Taylor Slough South, EII Reach 1 (TYS1)	20	Taylor Slough South Water Quality Retrofits

** Top 20 Priority Rank corresponds to map label in Figure 10.3-6 (Top 20 Priority Problem Areas: All Missions)*

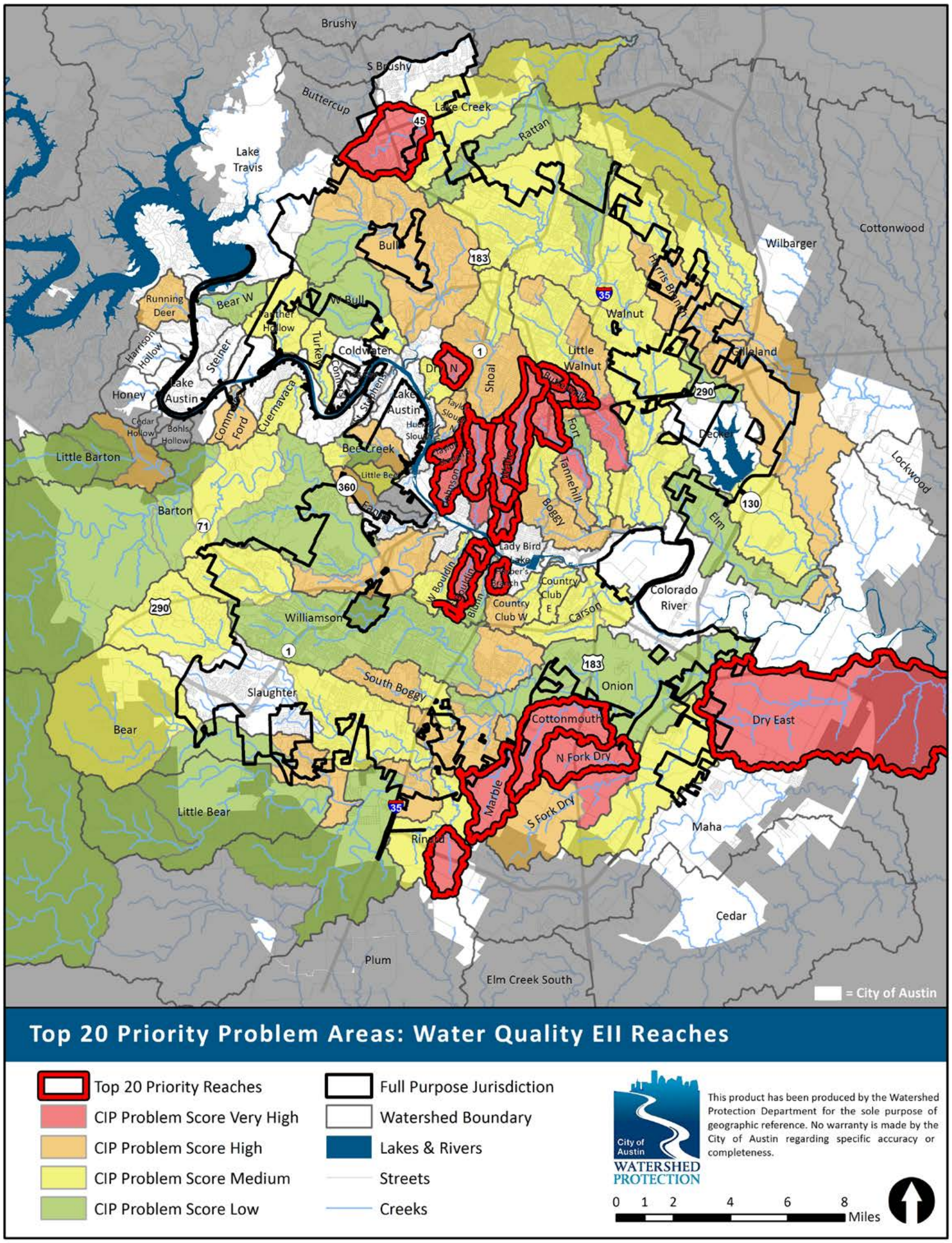

Figure 10.3-5 Top 20 Priority Problem Areas: Water Quality EII Reaches (October 2015)

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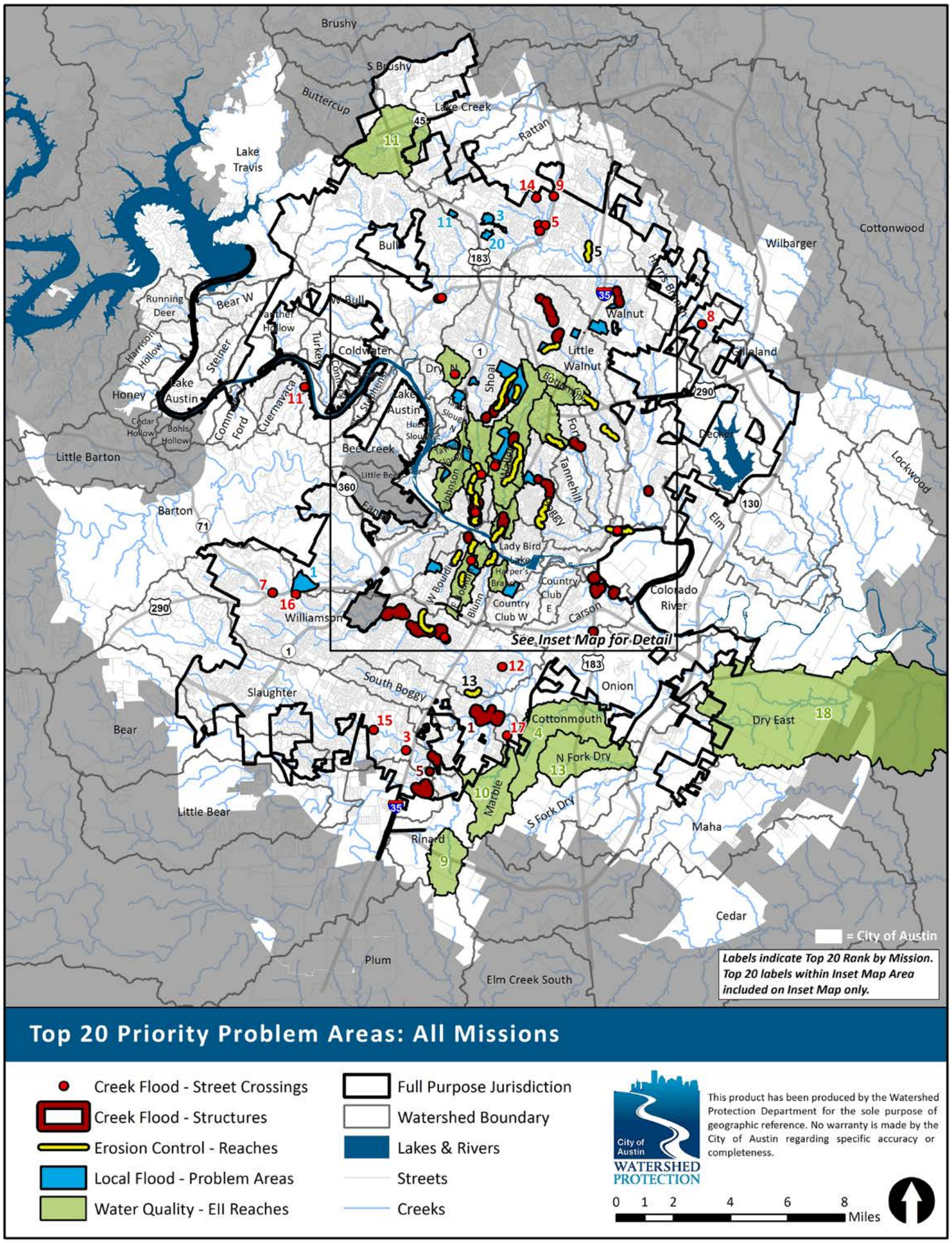

Figure 10.3-6 Top 20 Priority Problem Areas: All Missions (October 2015)

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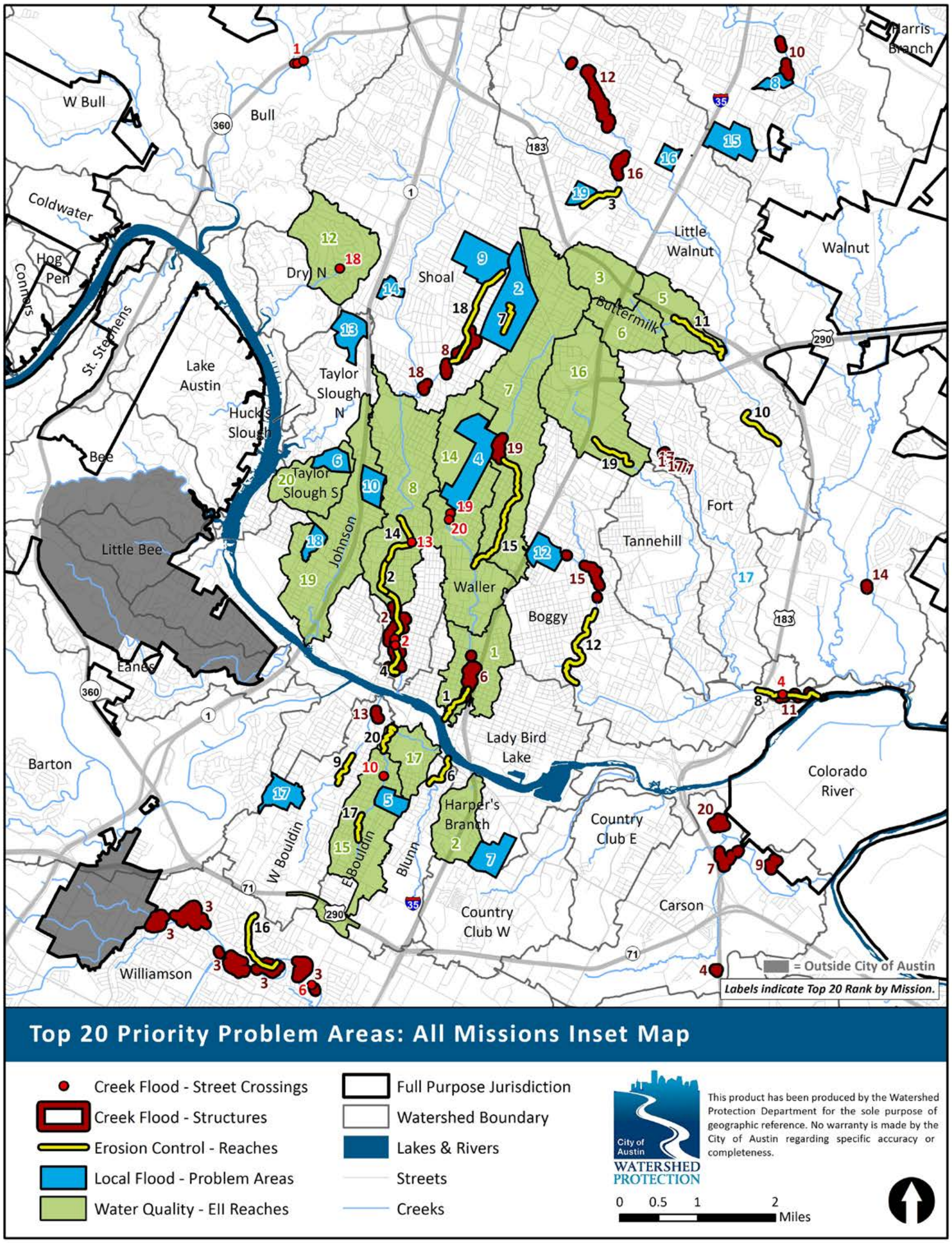

Figure 10.3-7 Top 20 Priority Problem Areas: All Missions Inset Map (October 2015)

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The project then proceeds to the design phase, where the same scoping process is completed by the MIP and VE teams. During the design, 60% design plans are reviewed to ensure that the design meets the desired project objectives. When the project has been constructed, the teams perform an evaluation of the project to assess the effectiveness of the project, determine if any monitoring should be conducted, and identify potential improvements for future projects. This process has led to successful project integration for all CIP projects that have received DUF, Urban Watersheds Structural Control Fund, and RSMP funding since Fiscal Year 2006.

A citywide effort has been initiated by the Capital Planning Office to achieve a stronger connection between the City's Capital Improvement Program and Imagine Austin Comprehensive Plan, with the goal of using our funding more strategically and minimizing disruption of services to the public. This process and its results are reflected in the Long-Range CIP Strategic Plan. This process includes an evaluation of overall citywide infrastructure needed to maintain existing and future levels of service, as well as an evaluation of strategic infrastructure investment. Imagine Austin provides the framework for the Long-Range CIP Strategic Plan. Also taken into account are legal mandates, critical infrastructure needs, and City policy initiatives including Neighborhood and Small-Area Plans. A separate process led by the Public Works Department coordinates capital improvement projects across all departments at a finer, project management level.

WPD, where possible, also identifies public-private partnerships to share costs and increase benefits to an area. For example, WPD and Development Services staff has worked with developers to manage and treat not only the required on-site runoff but also treat additional off-site stormwater runoff and/or construct storm drain systems and other conveyance improvements. The developer's costs are reimbursed, an economy of scale is achieved reducing costs to the City, and the improvements are built more quickly than might otherwise be possible.

10.3.2 Preferred Flood Mitigation Solutions

Once the Creek Flood mission High and Very High severity Problem Areas are identified, staff conducts an initial feasibility study to evaluate site conditions and note pertinent field data. The complaint database is also checked to see what information exists regarding flooding complaints from past storm events. Staff may obtain field survey elevation information to verify finished floor elevations against modeling data if deemed necessary.

As discussed in Section 4, separate flood problem scores are identified for flooded structures and for street crossings. Flooded structures have a variety of potential solution types that could theoretically resolve flooding problems. Both structural (e.g., detention, bridge and culvert upgrades, channel modifications) and nonstructural (property buyouts) solutions are evaluated, as well as a combination of structural and buyout, to determine the most feasible range of solutions. As a

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general rule, detention is most effective in the upper (upstream) third to upper half of the watershed. The availability of open space within the correct location within the watershed to place a potential detention pond is a key factor as to whether detention can be considered a viable solution. Bridge and culvert upgrades are evaluated as potential solutions for flooded structures if improvements in conveyance at the location of a bridge or culvert could reduce flooding of adjacent or downstream structures. If detention and bridge/culvert upgrades are infeasible or would not resolve the problem, channel modifications are then considered. Advancements in engineering design have resulted in newer, more environmentally-friendly channel modification design techniques that have gained popularity over the concrete-lined channels of the 1970s and 1980s. The City of Austin emphasizes sustainable design considerations with multi-mission benefits, and many stabilization techniques that rely on rock boulders and vegetative armoring have been implements by WPD with great success. These projects have been used for both erosion stabilization and creek flood mitigation projects and have a much lower environmental impact than the concrete channelization projects. However, riparian vegetation and other environmental considerations still factor into the overall evaluation whenever channel modifications are a potential solution.

Property buyouts are also considered as a potential solution for structure flooding. Depending on the specific location of the flooding, conditions of the creek and watershed, buyouts may be the only feasible, or the most cost-effective solution. WPD works closely with the Office of Real Estate Services to estimate the potential cost of a buyout alternative. Funding for buyout projects is first procured through the normal CIP budgeting process, and then City Council authorizes Real Estate Services to make and negotiate the offers.

Street crossings located within the City full purpose jurisdiction are evaluated for potential solutions. Street crossings located outside the City of Austin full purpose jurisdiction are referred to the County for solution implementation. In limited instances, the City of Austin and Travis County have jointly funded upgrades to low-water crossings where the street crossing was located in the county but was immediately adjacent to the City of Austin, and provided primary access to City residents who had no other safe access to their homes. The Thaxton Road Low-Water Crossing upgrade (5754.037) located in the Marble Creek watershed, was completed in May 2011, and is an example of such a joint partnership. Once the subset of street crossings located within the City's full purpose jurisdiction has been identified, staff evaluate site conditions, available field data, and flood model data to identify a cost for the high-priority bridge and culvert upgrades.

For both structure flooding and street crossings, High and Very High severity Problem Areas with feasible solutions then move forward to preliminary engineering analysis through the annual capital project appropriation process. At this time, all projects proposed for funding in the upcoming fiscal year will be reviewed for watershed integration potential by the MIP Team. Creek flood solutions are evaluated for the opportunity to integrate other mission goals into the project. Potential detention

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ponds are evaluated for the opportunity to provide water quality treatment and erosion control through extended detention. In-channel modifications are evaluated for impacts to/opportunities to benefit floodplain, natural and traditional character, priority woodlands, critical environmental features, and public land.

10.3.3 Preferred Local Flood Hazard Mitigation Solutions

Local Flood staff also use annually updated problem data to identify feasible capital solutions. Because the drainage complaint system is the data source for the Top 20 Priority Problem Area list, WPD conducts preliminary studies of the storm drain pipes in question to verify the extent of the problem. Each watershed sub-basin area is analyzed to compute excess runoff and size the main storm drain system. Information from the complaint database is used to supplement these studies. This analysis provides planning-level cost estimates for system upgrades used for the Master Plan. Figure 10.3-7 shows an example of a storm drain improvement evaluated using this process.

As the Drainage Infrastructure GIS (DIG) project nears completion, and data becomes available that better identifies system age, condition, and size, WPD will have the information necessary to begin modeling the storm drain system and will be able to identify long-term system needs in addition to the short-term system needs identified by current analysis.

Project concepts, described above, are furthered evaluated as they move to the implementation phase. This occurs on a yearly basis as part of the annual CIP budget appropriation process with the identification of the Top 20 Priority Problem Areas as determined using the problem score analysis described in Section 5. This information is coupled with the preliminary study described above to result in the identification of high priority storm drain projects which then go through the MIP Process to determine if additional watershed benefits could result. The outfall areas for the storm drain system are potential candidates for erosion stabilization. In some instances water quality benefits can be achieved by revegetation of the outfall area, or by providing rain gardens for stormwater treatment between the collection points and outfall locations in the creek. High priority storm drain projects are included for consideration as part of the five-year CIP plan (as Top 20 Priority Problem Areas).

Prudent engineering designs are essential to minimize negative impacts on other missions. Increased stormwater conveyance to reduce local flooding can, if not adequately designed, potentially destabilize streambanks cause increased flooding downstream. The project designer must evaluate the increased flow rates that result from an improved conveyance system and the timing of the discharge to the receiving stream with respect to flows already present in the receiving stream from other parts of the contributing watershed. A favorable timing of the improved tributary system with respect to the timing of the receiving stream might, in some cases, eliminate the need for

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RIDGELEA STORM DRAIN IMPROVEMENT

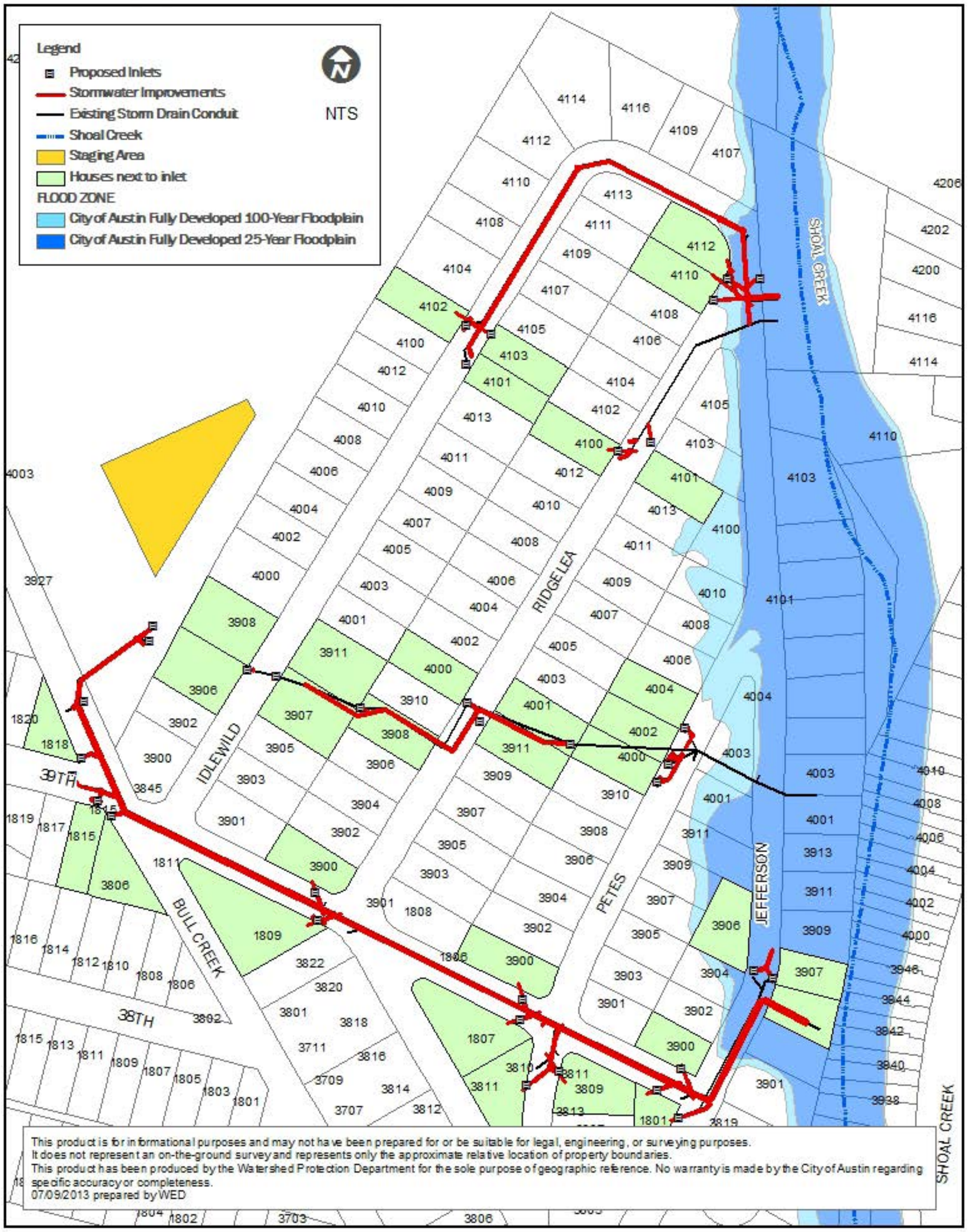

Figure 10.3-7 Ridgelea Storm Drain Improvements (2014)

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stormwater detention or other means to reduce the discharge rates. However, in other instances, it can be very challenging to eliminate local flooding without increasing flooding elsewhere.

Another consideration is the problem of streambank instability due to increased stormwater runoff. Prior to the City's adoption of its current regulations, increased development resulted in increased runoff which, in turn, caused receiving streams to grow in size, accompanied by a destabilization of the stream banks. The erosion of these banks continues and can only be rectified by improved stormwater controls that limit runoff volumes and duration, and/or through stream stabilization projects.

The City is currently evaluating the extent to which decentralized Green Stormwater Infrastructure (GSI) can be used to augment or replace traditional conveyance/detention approaches. A study is ongoing at the time of this update in the Brentwood neighborhood of the Shoal Creek watershed. For more information on the goals and preliminary results of this study, see Section 10.6.4 (Green Stormwater Infrastructure Team).

10.3.4 Preferred Erosion Streambank Stabilization Projects

The Erosion Control mission implements projects to decrease property loss, protect infrastructure, and increase the beneficial use of waterways. Each year, Erosion Control mission staff evaluate Very High and High severity Problem Areas for potential solutions. Solution types primarily include reach-based stream restoration, but structural erosion control, and property buyouts are also considered. Section 9.2.2 presents the full range of options. Preferred solutions include feasibility of implementation, expected cost, and overall public benefit. For residential structures at risk, the value of the structure is weighed against the cost of the project, along with the relative benefits to other watershed missions. Staff keeps bid tab information on the cost per linear foot of implementation of reach-based stream restoration projects, and uses this as an overall guide to determine the cost effectiveness of a proposed solution. While the majority of solutions implemented are reach-based restoration projects, erosion property buyouts have been implemented in limited instances where it was determined to be the most effective solution, or where due to the height of the bank, there were no feasible structural solutions. Examples of successful erosion buyouts include the Onion Creek Dixie Drive voluntary buyouts (805.005). This project began in 2003 and was completed in 2011 and was funded through a combination of use of the DUF and the 2006 general obligation bonds. Nineteen homes along a 35-foot vertical bluff along Onion Creek were ultimately purchased under this voluntary buyout program at an overall project cost of $2.8 million. A buyout was determined to be the most feasible and cost-effective solution.

Consideration is also given to whether or not project construction could be completed by a WPD Erosion Crew, or whether the project size, bank height, or other factors warrant a capital improvement

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project. As with all capital projects, the MIP process is completed as part of the preliminary project consideration, and the Problem Area is assessed to identify feasible opportunities for multi-mission benefits. Erosion projects may also incorporate stormwater management techniques such as infiltration areas, rain gardens, and pervious surfaces to mitigate adverse impacts of existing concentrated stormwater discharges into the project area. They are also evaluated to determine if in-channel modifications would benefit flood conveyance. Stabilization projects potentially have multi-mission benefits if they also result in improvements to flood or water quality scores. The resulting high severity erosion stabilization projects that require construction as a capital improvement project are included for consideration as part of the five-year CIP plan (as Top 20 Priority Problem Areas).

10.3.5 Preferred Water Quality Solutions

Water Quality Protection problem scores are also recalculated on a yearly basis as part of the annual capital budget appropriation process. Creek reaches which contain the Top 20 overall water quality problem scores are further evaluated to identify feasible capital water quality structural solutions using a targeted set of problem indicators. These problem indicators include toxins, altered hydrology, poor riparian zone/bank stability conditions, and nutrients from non-point sources other than leaking wastewater infrastructure—all of which can potentially be addressed with capital solutions (see Section 7 for a detailed discussion). Water quality problem scores are averaged over the most recent three evaluation years to buffer annual climatic variability and provide more temporal consistency in Problem Area rankings over time. Capital projects based on this evaluation which have been implemented include the One Texas Center Rain gardens, Warehouse Row Water Quality Retrofit, and the Lundelius-McDaniels water quality pond. Although resource value of the receiving water was previously considered in prioritizing Problem Areas, the current prioritization system focuses on the problem scores to provide an objective, citywide prioritization scheme.

Water quality structural solutions can include conventional wet ponds and sedimentation-filtration ponds or, more frequently in recent years, green infrastructure controls such as bioretention ponds or rain gardens, which provide additional community benefits and meet a specific objective of the Imagine Austin Comprehensive Plan.[2]

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[2] Since the original 2001 Master Plan, a number of new technologies have been refined that focus on implementing green infrastructure. Green infrastructure, when used in the context of stormwater management, uses smaller-scale, decentralized treatment devices to mitigate the effects of urban development. Green infrastructure often incorporates vegetation and landscaped areas into the treatment process, thereby allowing space to be used more effectively. Since they are individually smaller in scale, green infrastructure projects can be dispersed and integrated into the site and used to help meet landscaping requirements, allowing flexibility for water quality compliance for denser projects. This contrasts with conventional "end-of-pipe" centralized controls, which typically occupy a larger contiguous space and treat the entire developed area in one pond. The Environmental Criteria Manual Section 1.6.7 (Green Stormwater Quality Infrastructure) has been continuously updated to include and improve criteria for several of these controls. These green infrastructure technologies are part of the menu of potential SCMs that are evaluated for implementation once a water quality Problem Area has been identified.

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The Very High severity water quality problem scores are the primary drivers that identify the highly impacted areas that need mitigation. Once identified, a project moves to the feasibility level evaluation. Consideration is given to determining the individual components of the water quality problem score to determine the driving cause for the degradation. These Problem Areas are then evaluated to determine whether or not an engineered solution can be implemented to decrease the water quality problem score. Structural water quality controls are the primary means of improving conditions in reaches afflicted by the problem drivers identified with the CIP water quality problem scores: toxins in sediment, poor riparian vegetation, unstable channels, and nutrients (non-sewage). Non-structural controls such as stream restoration may also be incorporated into water quality retrofit projects to prevent erosion and associated sediment load and/or to enhance the riparian habitat to improve a water quality problem score. The stormwater pond geodatabase is examined to look for previously identified retrofit opportunities, which include new retrofit opportunities as well as opportunities to retrofit existing stormwater infrastructure to add/maintain water quality functionality and enhance the level of treatment. Current aerial photos, City-owned parcels, City Right-of-Ways, and Travis Central Appraisal District maps are reviewed to determine the availability of space for a project. Once a project concept is developed, staff determines rough design/construction/land costs and estimates potential pollution removal to calculate cost-effectiveness of preliminary solutions. Projects that pass this initial screening protocol are then reviewed for other factors that could limit the project feasibility, such as underground utilities that could significantly increase costs. As these projects are evaluated, consideration is given to potential integration of flood and erosion mission goals where feasible. For example, stream restoration may also be incorporated into water quality retrofit projects to prevent erosion and associated sediment load and/or to enhance the riparian habitat to improve a water quality problem score. Potential solutions are then forwarded for consideration as part of the five-year capital budget process (as Top 20 Priority Problem Areas).

Potential improvements to riparian zones are identified separately. Riparian zones are critical to maintaining habitat diversity, stream stability, and improving stormwater runoff quality. ERM staff developed a system to prioritize sites with narrow, poor quality riparian zones based on visual assessments from the Habitat Quality Subindex (a component of the Environmental Integrity Index) and using a GIS-derived Index of Riparian Integrity (IRI) (see Section 7). Sites are identified for potential restoration through WPD's Riparian Zone Restoration program. City-owned lands with degraded riparian zones are given special priority due to increased feasibility (including access, maintenance considerations, no easements required). All potential sites are also evaluated to determine if a change in management practices can be done without adversely impacting flood conveyance. Improved management may be done by WPD's Vegetation and Land Management Program (responsible for the City-contracted mowing of riparian zones) or by the Parks and Recreation Department (see Section 9.3.1.11: Vegetation and Land Management Program). Riparian restoration strategies generally focus on managed succession from a disturbed (mowed) condition

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to a more functional condition. WPD capital dollars provide for materials including seed, plants, signage and irrigation when necessary. Labor costs are offset in part by collaborating with area non-profit advocacy groups (Austin Parks Foundation, Keep Austin Beautiful) and adjacent neighborhood groups who adopt restoration areas and assist with plantings activities, invasive species removal and maintenance as necessary.

10.4 Assessing Benefits and Costs of Capital Solutions

The 2001 Master Plan presented estimates of the benefits and costs to implement various capital solution alternatives developed for the Phase 1 watersheds. The present Master Plan updates these estimates and adds new estimates for the Phase 2 watersheds for which data is available. The 2001 feasibility determination was based on very preliminary site investigations. Therefore, the resulting benefit and cost estimates should also be considered as broad, planning-level estimates. They give an "order of magnitude" type of figure for the funding level needed to make these improvements. Each year, as part of the City's capital projects appropriation process, project costs are refined based on additional investigation of the Problem Areas and potential solutions. Projects selected for funding are further evaluated during the preliminary engineering phases of the capital implementation process to better define proposed project budgets and objectives.

This present Master Plan includes updated 2001 Master Plan project costs using the best available data. These updates are based on the initial 2001 project cost estimates, supplemented with cost estimates for capital projects identified as part of the Rolling Needs Assessment, a component of the City's 2015 - 2016 Long-Range Capital Improvement Program Strategic Plan, as well as additional updated project costs where available. The 2001 Phase 1 cost methodology is summarized below. As part of the 2015 update, watershed costs were revised to update costs for known Phase 2 watershed costs, including Onion and Carson Creek, and limited improvements in Bear, Brushy, Dry North, Dry East, Harris, Lake Creek, Lake Austin, Lady Bird Lake, Little Bear, Marble, Rattan, Slaughter, and Taylor Slough watersheds, as well as updated project costs for Phase 1 areas. These updated costs are presented in Table 10.4-1, with an estimated cost of $2.2 billion to implement solutions for the Creek Flood, Local Flood, Erosion Control, and Water Quality Protection missions. This updated cost data was based on preliminary cost estimates, including estimates from feasibility and preliminary engineering reports. Costs are preliminary in nature. Cost estimates represent the total cost to retrofit a watershed, where this information is known, and in many instances include projects that have been completed or are underway. The next update to this Master Plan will separate out the problems remaining to be solved.

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Table 10.4-1 Capital Solution Cost by Watershed

Watershed	Creek Flood	Local Flood	Erosion	Water Quality	Total
Barton	$1,627,000	$4,100,000	$2,640,000	$33,945,500	$42,312,500
Bear	$1,650,000				$1,650,000
Blunn	$4,820,000	$5,105,739	$2,230,000	$2,833,000	$14,988,739
Boggy	$14,320,000	$27,667,783	$12,118,287	$6,845,000	$60,951,070
Brushy	$810,000				$810,000
Bull	$24,420,000	$14,385,000	$10,850,000	$43,420,000	$93,075,000
Buttermilk			$4,880,000	$4,391,000	$9,271,000
Carson	$36,384,387				$36,384,387
Country Club (E & W)	$15,810,000	$21,005,000	$6,390,000	$7,950,000	$51,155,000
Dry East				$1,100,000	$1,100,000
Dry North	$3,500,000			$1,100,000	$4,600,000
East Bouldin	$25,680,000	$15,070,000	$7,514,000	$7,090,000	$55,354,000
Fort Branch	$22,521,000	$16,456,239	$9,930,000	$3,240,000	$52,147,239
Harpers Branch		$2,600,000	$260,000	$5,488,000	$8,348,000
Harris Branch	$3,850,000				$3,850,000
Johnson	$4,300,000	$15,200,000	$5,610,000	$3,291,000	$28,401,000
Lady Bird Lake		$27,700,000		$316,682	$28,016,682
Lake Austin	$2,200,000	$4,500,000		$1,347,391	$8,047,391
Lake Creek				$1,100,000	$1,100,000
Little Bear		$30,604,071		$10,850,000	$41,454,071
Little Walnut	$99,990,000		$13,440,000	$14,273,000	$158,307,071
Marble	$3,184,000			$1,099,000	$4,283,000
Onion	$140,000,000		$3,015,000	$27,198,000	$170,213,000
Rattan	$733,000			$2,198,000	$2,931,000
Shoal	$209,690,000	$98,310,827	$21,360,000	$29,450,000	$358,810,827
Slaughter	$13,819,397			$1,334,319	$15,153,716
Tannehill Branch	$2,120,000	$8,400,000	$8,520,000	$6,836,571	$25,876,571
Taylor Slough		$6,101,000		$500,000	$6,601,000
Waller	$185,320,000	$39,400,000	$23,260,000	$10,770,000	$258,750,000
Walnut	$60,380,000	$23,399,000	$36,890,000	$55,910,000	$176,579,000
West Bouldin	$8,131,000	$26,069,067	$3,140,000	$13,680,000	$51,020,067
Williamson	$108,620,000	$29,699,540	$18,960,000	$50,260,000	$207,539,540
CBD		$68,000,000			$68,000,000
TODs/UNO		$246,666,000			$246,666,000
Total	**$993,879,784**	**$730,439,266**	**$191,007,287**	**$347,816,463**	**$2,263,142,800**

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During the 2001 investigations, creek flood Problem Areas were ranked based on the overall flood problem scores within the flood Problem Area. As part of the initial 2001 Phase 1 Master Planning effort, the top 32 ranked Problem Areas were designated as "Level I" Problem Areas and were evaluated with a more detailed protocol than the remaining 140 areas, which were designated as "Level II" Problem Areas. This initial project concept identification was used as the basis for providing a planning-level cost estimate for creek flood solutions.

The 2001 Master Plan presented only very limited Local Flood capital project information. Ultimately, construction costs depend on the results of final design configurations and the length of time required for implementation. Costs for storm drain systems have been updated since the 2001 Master Plan, and are shown in the table above. These costs represent only a limited number of storm drain upgrades based on high priorities as identified by citizen complaints. Because WPD does not yet have citywide storm drain models, comprehensive cost estimates for upgrades to the citywide stormdrain system are not yet possible. Section 5 discusses the current and proposed methodology for analyzing storm drain system needs. Costs for storm drain system upgrades for Phase 1 and 2 watersheds are provided for projects which have cost estimates entered into the City's CIP database, eCAPRIS, and also for those projects identified as part of the 2015-2016 Rolling Needs Assessment. A future Master Plan update will update storm drain cost information as additional projects are identified and cost estimates are developed.

The 2001 Master Plan process identified erosion stabilization projects by combining Type 1, Type 2, and Type 3 erosion problem locations into project units. Project units are groupings of erosion problems based upon physical proximity of localized erosion problems and reach characteristics. Not all Type 2 and 3 problems were assigned an erosion project; only the 47 highest rated areas were included. Preference was given to softer technologies, such as vegetative reinforcement or bioengineering, because they are more sustainable and use natural products that promote revegetation and protect the natural character of waterways. This minimizes future maintenance, and enhances a stable stream system. These techniques also allow for multiple uses of waterways by facilitating recreational opportunities. A preliminary assessment of all proposed side-slope project locations was completed in the 2001 Phase 1 Master Plan to identify possible locations where vegetative approaches might be appropriate. This evaluation was used to identify the planning-level cost estimate for erosion solutions. The original Erosion Control project cost estimates were based on studies of Phase 1 waterways with one square mile (640 acres) or greater of drainage area—the cutoff for the 1997 Erosion Assessment studies. Many erosion problems develop in smaller waterways, and thus the costs presented in the 2001 Master Plan are not comprehensive. Today's project identification methodology, however, does include methods to include projects on smaller waterways, e.g., those identified via citizen complaints or staff field analyses, and projects are developed to address all High and Very High severity Problem Areas, regardless of their drainage threshold. Future Master Plan Updates will include all potential project costs to improve this cost estimate.

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The 2001 Master Plan focused its water quality capital estimates for costs and benefits primarily on large, residential–scale ponds for treatment and erosion control. Smaller-scale options, such as what we now term “Green Stormwater Infrastructure,” were included in the solutions inventory, but no attempts were made to include these in the cost-benefit or goal attainment calculations. The difficulty of finding suitable sites for large controls in urbanized watersheds has since led WPD to explore the development of small-scale CIP solutions such as green stormwater infrastructure and riparian restoration. The capital cost update includes cost estimates for green infrastructure and riparian restoration projects where cost estimates are available.

10.4.1 Project Benefit and Level of Service

As part of the MIP Integration and VE Team processes, information on project benefits is weighed relative to project costs. WPD continues to refine and improve methods of assessing project benefit for all missions. The Water Quality Protection and Erosion Control missions have both developed in-house techniques for evaluating the benefit of projects based on unit cost. The Water Quality Protection mission calculates the average cost of sediment removal for sand filters, which have a high standard of efficiency, and use this cost per pound of total suspended solids removed as a basis by which the benefits of other types of controls can be weighed relative to cost. The Erosion Control mission calculates the average cost per linear foot of stream bank restored based on bid tab information maintained by the Public Works department, and uses this to evaluate the cost benefit of proposed projects, and to help select project alternatives. Assessing project benefit relative to project cost has not yet been defined on a departmental level for the Local Flood mission, although improvements have been made, especially for storm drain projects, through incorporation of storm drain data from the Drainage Infrastructure GIS (DIG) project discussed in Section 3.1, and through advances in modeling software. Development of an “Acceptable Level of Service,” discussed in Section 10.4.2 below, will also help in the effort to uniformly upgrade all project cost estimates for the Master Plan, and better relate them to goal achievement.

10.4.2 Infrastructure Costs and Asset Management

As part of the Capital Planning Office’s Comprehensive Infrastructure Assessment, included in the 2015-2016 Long-Range Capital Improvement Program Strategic Plan, WPD continues to work on the definition of existing and Acceptable Levels of Service (LOS) for all watershed related infrastructure, including stormwater ponds, creeks, stormdrain lines, inlets and related component’s, bridges and culverts. Once the LOS has been defined, assessing the gap between current conditions and achieving Acceptable Level of Service will help identify costs of repair and replacement of WPD’s Infrastructure assets. This cost is currently not included in Table 10.4-1, which only identifies high priority infrastructure upgrades needed to solve identified watershed problems. Developing a long-range asset management plan is a high priority strategic departmental need to address our aging infrastructure.

10.5 Identifying Preferred Programs

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Operating programs were evaluated in several ways. The 2001 Master Plan included a Level of Service Study as well as benchmarking of programs in other U.S. cities, which resulted in a number of recommendations for program enhancements and a limited number of new programs. With the exception of very few items, all program enhancements from these original recommendations have been implemented or are underway. Implementation efforts for these recommendations are included in Appendix D of this report. In many instances, additional enhancements have since been implemented that go beyond these original recommendations. Examples of this include the many additional watershed educational campaigns that have been undertaken beyond the Grow Green program recommendation from 2001, as well as the new riparian restoration and Grow Zone activities undertaken by the Surface water Evaluation program.

The introduction of the Maximo application, discussed in Section 8.4 (Computerized Maintenance Management System), is an excellent example of implementation of additional program enhancements. Maximo now assists in tracking the condition of the storm drain infrastructure, as well as work and materials completed by WPD field crews to maintain this system, allowing for the creation of reports of materials cost and labor associated with this maintenance. This information is not only useful as a management tool for Field Operations, but also provides information to document compliance with the federal stormwater permit (TPDES) administered by the Intergovernmental Compliance program. In addition to tracking completed maintenance, Maximo can be used to establish work priorities, schedule preventative maintenance activities, and to manage inventory of materials and parts. In addition to these benefits to the field operations programs, Maximo contains a database used for erosion problem score data, as well as additional databases under development for spills and complaint data, and the Stormwater Discharge Permit Program.

Updated program recommendations and new program development included in this Master Plan have primarily been based on interviews with staff, including the interdisciplinary teams discussed below as well as feedback from the Environmental Commission, which has acted as the formal advisory group for WPD since the original Citizen's Advisory Group was dissolved upon adoption of the Master Plan in 2001. The goal of these program recommendations is to raise the level of service, improve program performance, address asset management needs, and keep up with Austin's rapid rate of growth. The recommendations are summarized in Section 11.

10.6 Value Engineering and Interdisciplinary Teams

A Value Engineering (VE) team was created in 2009 to optimize CIP projects, programs, and regulations by identifying opportunities for cost, functional, and process improvements. Three interdisciplinary teams were created in 2011 to generate discussion and collaboration between

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missions on the topics of modeling, data management, and green stormwater infrastructure. This cross-functional approach was based on the existing Mission Integration and Prioritization Team (MIP), discussed above in Section 10.3.1. The goals and recommendations outlined for each team below reflect input collected during the present update's revision process.

10.6.1 Value Engineering Team

Value Engineering (VE) is a systematic and function-based approach to maximize the value of capital projects, programs, and regulations by identifying opportunities for cost savings, cost avoidance, and function/process improvements. The VE team is an independent review entity that follows a structured process and operation protocol with the following objectives:

- Stretch WPD CIP dollars and get the best value out of CIP projects or service programs;
- Maximize project product functions, values, and services;
- Minimize project cost, long-term operations and maintenance cost, and potential adverse impact on community, environment, and economy;
- Promote efficient, environmentally friendly, and sustainable designs and operation; and
- Review WPD CIP project scopes, preliminary engineering reports, 60% design plans, engineering products, and service programs in an organized, timely process.

The VE team works independently of the MIP Team, but does typically attend MIP Team meetings and generally follows the same review process to ensure a timely and coordinated review.

10.6.2 Modeling Team

The mission of the Modeling Team is to pool the knowledge and expertise of WPD staff across missions to improve the application of numerical modeling for hydrologic, hydraulic, and water quality analysis. The goals of the Modeling Team include:

- Coordinate WPD modeling efforts to reduce duplication of effort and increase compatibility where possible;
- Evaluate and recommend alternative models for use by WPD missions and programs;
- Provide technical assistance and training to WPD staff and programs with respect to modeling surface and groundwater hydrology, hydraulics, and water quality;
- Provide recommendations to the director on whether to approve or deny proposals for the use of alternative models by permit applicants; and
- Coordinate WPD modeling efforts with Land Use Review staff from the Development Services Department.

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10.6.3 Data Team

The Data Team is a cross-functional group composed of members from each business unit in Watershed Protection that provides opportunities for employees engaged in IT-related roles or highly-data-dependent business units to share ideas and understand the forward direction of departmental IT. Data Team members' experience is leveraged to identify the key functional requirements of our workgroups and create an inventory of data, applications, and IT skillsets required to inform the Information Management Plan. Watershed Protection used the work of the Data Team through the City Manager's Open Data Initiative to maximize citizen access to our data so that they may have a better understanding of the efforts put forth to achieve excellence in our core missions.

10.6.4 Green Stormwater Infrastructure Team

The Green Stormwater Infrastructure Team was formed in 2011 to advance the application of green infrastructure approaches to stormwater management in Austin. Green infrastructure for stormwater management reduces impacts from built environments using landscape features and engineered systems that mimic natural processes to provide flow-rate attenuation, volume reduction, and water quality improvement. The team concluded its work in 2015. The objectives of the Green Stormwater Infrastructure Team included:

- Create a common body of knowledge regarding green stormwater infrastructure technology, regulations, and community acceptance for Watershed Protection and the City of Austin;
- Identify opportunities for the application of green stormwater infrastructure in City-sponsored retrofits, private development, and voluntary homeowner projects;
- Identify implementation and long-term maintenance constraints;
- Create delivery plans for specific green stormwater infrastructure projects (e.g., regulatory changes, maintenance protocol, public outreach)

The team served as a knowledgeable clearinghouse of information for those interested in implementing Green Stormwater Infrastructure solutions. Although the team did not sponsor construction projects, write rules, or maintain controls, individual team members, via their mission or program, used the knowledge gained from the forum to solve problems by exploring the appropriate use of green technology. Given the successful integration of green infrastructure knowledge and approaches into the missions and programs, the Green Stormwater Infrastructure Team was retired in 2015. However, the work of the team continues through the individual missions and programs as well as the Imagine Austin Priority Program Teams for green infrastructure and sustainable water management.

The keystone project of the team was to evaluate the extent to which decentralized green stormwater infrastructure can be used to augment or replace traditional conveyance/detention ("grey") approaches in the Brentwood neighborhood of the Shoal Creek Watershed. The study uses advanced modeling techniques to examine opportunities to address flooding, channel erosion, and water quality problems with distributed, small-scale green stormwater infrastructure. The Brentwood area drains to the eroded Hancock Branch tributary of Shoal Creek that exceeds its conveyance capacity in storm events as frequent as a 2-year storm. Within the Brentwood area, the expense of construction of the fully re-designed storm drain system is cost prohibitive. Furthermore, the City faces design constraints because a proposed improvement cannot create an adverse impact to the receiving channel, which is projected to occur from a conventional upgrade and replacement of the existing system.

The objectives of the study are to demonstrate the extent to which green stormwater infrastructure can meet the following goals:

1. Reduce the frequency, magnitude, and duration of peak flows to reduce the frequency of flooding;
2. Reduce the volume of runoff and increase the volume of infiltration;
3. Reduce or eliminate the anticipated life-cycle costs of system-wide stormwater conveyance upgrades;
4. Reduce pollutant loads and erosion potential to receiving waters;
5. Reduce the use of potable water for landscape irrigation; and
6. Avoid adverse impacts to the base flood elevations of Shoal Creek.

Preliminary results from the study show that using a hybrid approach of both decentralized green infrastructure and targeted storm drain upgrades virtually eliminates localized flooding for smaller (less than 10-year) storms with no adverse impact to the downstream floodplain. Localized increases in drainage efficiency appear to be offset by the overall hydrologic load reduction provided by the green infrastructure features in the watershed. The model also showed a significant reduction in the number of structures flooded by greater than 10-year storms, although many structures would still potentially be inundated in these larger storms. For water quality, this approach would achieve annual load reductions of 50,000 pounds for total suspended solids. The final results of the study are not available at the time of this writing but will be included in a future Master Plan update.

Additional team projects included creation of a maintenance manual for Green Stormwater Infrastructure as well as a benchmarking effort to better understand how other cities use green infrastructure as a tool for managing flooding, erosion, and water quality. Seven cities were selected to participate, based primarily on an existing reputation as leaders in the field of green infrastructure. Other factors were also considered to ensure a diversity of answers as well as experience relevant to Austin, including climate, rainfall patterns, combined versus separated sewer, and population. The cities chosen were Chicago, New York City, Philadelphia, Phoenix, Portland, Seattle, and Tucson.

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The benchmarking effort resulted in four major findings:

- Majority of respondents give credit to vehicular porous pavement;
- Most respondents allow combined storage of water quality and detention volumes;
- Majority of respondents do not allow stormwater credit for decentralized controls on individual single-family lots; and
- Most respondents allowed stormwater credit for green roofs.

The results of the benchmarking effort were used to make recommendations on changes to code and criteria as part of the Watershed Protection Ordinance. Staff may choose to conduct more thorough follow-up interviews in the future to investigate potential improvements to programs related to modeling, education and outreach, or inspection and maintenance.

10.6.5 CodeNEXT Team

The Watershed Protection Department has been tasked with leading the revisions to the City's drainage and water quality regulations as part of the CodeNEXT Land Development Code revision process. For more information on CodeNEXT, see Section 10.7.2. This interdisciplinary team will rely on expertise from across the department to perform the following functions:

- Develop technical recommendations to implement the goals and vision of Imagine Austin and the Green Infrastructure Working Group.
- Make official recommendations for review and discussion.
- Help draft and review code language and graphics to be submitted.
- Review and provide comments on draft code products.

10.7 Identifying Preferred Regulations

Based on the watershed problems identified in the 2001 Master Plan, an analysis of potential regulatory initiatives was performed to determine if: (1) enhancements to existing regulations would address identified watershed problems and help achieve WPD goals, and if (2) new regulations were needed to address identified watershed problems and achieve WPD goals. The status of these recommendations can be found in Appendix E of this report. With the 2013 adoption of the Watershed Protection Ordinance, summarized below, 27 of the 29 regulatory recommendations from the 2001 Master Plan have been completed.[3]

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[3] See Appendix E for the remaining two items: (1) a **Golf Course Management Plan** is no longer considered necessary at this time and (2) changes to **Effluent Irrigation Standards** for wastewater application are no longer possible as these regulations are now the sole purview of the State of Texas.

10.7.1 Watershed Protection Ordinance (WPO)

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On October 17, 2013, the Austin City Council passed a new Watershed Protection Ordinance (WPO) to improve creek and floodplain protection, prevent unsustainable public expense on drainage systems, simplify development regulations where possible, and minimize the impact on the ability to develop land. The effort was the first of its kind since the City's Comprehensive Watershed Ordinance (CWO) was enacted in 1986. This request included items that were very complementary with recommendations from the 2001 Master plan, including headwater stream protection, stream setbacks, volumetric detention, and expansion of mitigation opportunities. The City Council initiated the WPO Watershed by resolution on January 13, 2011. The City held an extensive series of stakeholder meetings with over 200 participants from August 2011 through June 2013 to obtain public input.

The ordinance is organized around the seven major themes of the Council resolution:

1. *Creek Protection*. The regulatory recommendations of the 2001 Master Plan called for improvements to stream setbacks to preserve native vegetation, protect against erosion threats, and promote headwaters protection. A major cornerstone of the new ordinance is the citywide extension of critical water quality zone setbacks to headwaters streams with 64 acres of drainage. This change is most significant in the eastern Suburban watersheds, which previously only protected streams with a drainage area of at least 320 acres. The new ordinance now protects an estimated 363 miles of additional headwaters stream mileage in Suburban watersheds alone. Another fundamental part of the ordinance is the establishment of an Erosion Hazard Zone and the prohibition on development within this setback. Additional provisions ensure that improvements within the Critical Water Quality Zone, such as parks and trails, minimize disturbance to existing vegetation and drainage patterns.

2. *Floodplain Protection*. Another major revision of the ordinance was to adjust the approach to protecting and enabling the recovery of degraded waterways by strengthening rules for floodplain design and modification. Proposed development will need to plan for fully vegetated, natural floodplains rather than altered, mowed floodplains. Floodplain modification is prohibited within the Critical Water Quality Zone, except for modifications that provide for public health and safety, significant environmental benefit, and development already permitted (e.g., road crossings). In addition to these exceptions, floodplain modification is allowed outside of the Critical Water Quality Zone if a functional assessment of floodplain health determines the area to be in poor or fair condition. Modification must be offset through on-site restoration or off-site mitigation where restoration is infeasible.

3. *Development Patterns and Greenways*. The ordinance added several provisions to promote the connectivity and local food goals of Imagine Austin as well as the Master Plan goal of fostering additional beneficial uses of waterways. WPO clarified that trails and sustainable urban agriculture

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are permitted conditionally within the Critical Water Quality Zone. The ordinance also improved and expanded the menu of elements that Planned Unit Developments choose from to demonstrate superior environmental protection.

4. *Improved Stormwater Controls*. To improve structural stormwater controls, the ordinance revised the current threshold for water quality controls from 20% of net site area to 8,000 square feet, requires controls to be accessible for maintenance and inspection, and requires maintenance plans and third-party inspections for subsurface controls. In addition, the ordinance removed the requirement for isolating the water quality volume from larger flood flows. More significant changes are anticipated as part of Phase 2 of the Watershed Protection Ordinance, including the following topics:

- Limit stormwater runoff volume (e.g., requirements for infiltration or re-use on-site);
- Rain gardens for single-family residential subdivisions;
- Alternative structural control options for SOS compliance;
- Rainwater harvesting for water conservation and water quality;
- Use of green roofs as irrigation areas for rainwater harvesting;
- Porous pavement for non-pedestrian surfaces (e.g., parking lots);
- Flood detention credit for water quality controls;
- Impervious cover credit for rainwater harvesting catchment areas;
- Volumetric Flood Detention (add to Drainage Criteria Manual as option); and
- Other related items as identified by stakeholders.

5. *Mitigation Options*. The regulatory recommendations of the 2001 Master Plan called for a development mitigation policy, including the use of transfer of development rights to preserve open space and natural areas within the watersheds. The Watershed Protection Ordinance improved the existing, limited transfers of development rights sections within the Code to allow for increased flexibility and protection of additional environmental resources (floodplains or environmentally sensitive areas). In addition, the ordinance extended the Barton Springs Zone Redevelopment Exception to the rest of the Water Supply watersheds. This exception uses a similar mechanism, allowing sites to keep their current impervious cover in exchange for providing water quality controls and providing off-site mitigation, such that impervious cover limits are achieved across the two sites.

6. *Simplifying Regulations and Maintaining Opportunity*. The resolution from Council called for the ordinance to "simplify development regulations where possible and minimize the impact of any changes on individual and collective abilities to develop land." In order to offset impacts from the new core protections of this ordinance, a number of trade-off provisions were added for the eastern Suburban watersheds, including:

- Using gross site area (instead of net site area) to calculate impervious cover;
- Eliminating the Water Quality Transition Zone;

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- Allowing “buffer averaging” to reduce the width of buffers by up to one-half if the overall amount of area protected remains the same; and
- Allowing additional uses within the upper half of the critical water quality zone, including green stormwater controls and utilities.

In addition to these offsets, a large number of clarifications and corrections of existing code and policy interpretations were included as well.

7. *Coordinate with Regional Partners*. Staff worked closely with Travis County throughout the ordinance development process to align and coordinate regulations where possible. The proposed amendments to Title 30, which apply to subdivisions in the ETJ, will need to be approved by the Travis County Commissioners’ Court prior to adoption.

10.7.2 CodeNEXT

One of the eight key “priority programs” of the Imagine Austin Comprehensive Plan is to “revise Austin’s development regulations and processes to promote a compact and connected city.” Austin’s City Charter requires that land development regulations be consistent with the Comprehensive Plan. Significant revisions to existing regulations will be necessary to fully implement the priority programs and to promote a compact and connected city that depends less on the car and more on walking, bicycling, and transit to access daily needs. Achieving these goals will require a comprehensive review and revision of the Land Development Code, associated technical and criteria manuals, and administrative procedures. This major reworking of the Land Development Code, led by the Planning and Zoning Department and Opticos Design, is known as CodeNEXT.

Goals of the revision include:

- Complete neighborhoods and expanded housing choices;
- Neighborhood protection;
- Household affordability;
- Environmental protection;
- Efficient service delivery; and
- Clear guidance and format.

WPD staff led a stakeholder process in 2015 that brought together the public, members of the CodeNEXT citizen advisory group, and staff from multiple departments to help identify critical issues and provide recommendations on potential changes. Stakeholders included engineers, landscape architects, neighborhood representatives, environmental groups, developers, and concerned citizens. This stakeholder process, known as the Green Infrastructure Working Group, was one of five CodeNEXT public working groups. Per City Council request, the Green Infrastructure Working Group examined how the City can achieve the Imagine Austin goals of integrating nature into

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the city, sustainably managing our water resources, and creating complete communities through revisions to our zoning and environment codes. The themes and goals of the Green Infrastructure Working Group are summarized in Table 10.7-1.

The input from the Green Infrastructure Working Group is being incorporated into the staff recommendations for CodeNEXT. In advance of public review of the entire code in 2017, the CodeNEXT team is previewing how the new code will address critical topics such as the environment, mobility, and affordability by publishing four "prescription papers" in 2016. The following recommendations related to watershed protection were included in the Natural and Built Environment prescription paper:

- Maintain Austin's historic watershed regulations and recent Watershed Protection Ordinance improvements.
- Maintain our current code's strong emphases on preservation of existing topography, native vegetation, and environmental health.
- Incremental redevelopment should occur in step with an evaluation of infrastructure, including drainage capacity.
- Redevelopment—like new development—will be required to mitigate for the site's share of existing downstream flooding. This means reducing post-development peak rates of discharge to match peak rates of discharge for undeveloped conditions.
- New and redevelopment sites will be required to retain and beneficially use stormwater onsite. This means requiring sites and subdivisions to prevent off-site discharge from all rainfall events less than or equal to the 95th percentile event through practices that infiltrate, evapotranspire, and/or harvest and use rainwater.
- Promote land cover that performs multiple ecosystem functions, requires fewer resources, and provides better planting environments for a more sustainable urban landscape.
- Encourage the incorporation of low-impact development in coordination with landscaping standards. In addition, incentivize designing green infrastructure with dual active recreation options to meet multiple purposes in the code.

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Table 10.7-1 Green Infrastructure Working Group Recommendations

Theme	Goals
Land Cover and Natural Function	• Ensure adequate natural function for all sites, including greenfield and redevelopment/infill sites • Promote desirable, purposeful open spaces that enhance connectivity • Design the built environment to take advantage of the strengths of both pervious and impervious cover
Integrate Nature into the City	• Promote functional landscapes with multiple benefits (e.g., urban heat island, water conservation, habitat, enhanced public realm) • Preserve and replenish the urban forest • Enhance climate resilience and adaptation to drought • Add green transitions between different land uses • Ensure the new ordinance is practical to implement and maintain
Beneficial Use of Stormwater	• Address drought and climate change impacts on watershed health and water supply • Require some level of infiltration and/or re-use of stormwater on-site for new & redevelopment
Stormwater Options for Redevelopment/ Infill	• Address longstanding problems due to development without sufficient flood controls and/or drainage conveyance • Provide additional flexibility and options to enhance water quality for redevelopment and infill

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11 Recommendations

This section summarizes the findings and recommendations of the Watershed Protection Master Plan. It discusses the watershed goals and objectives and the prospects of their attainment. It then discusses future implementation of capital, programmatic, and regulatory solutions, concluding with overall findings and recommendations.

11.1 Estimating Goal Attainment

The Watershed Protection Master Plan presents individual and common goals for watershed protection. These goals, originally established in 2001, remain unmodified in this present update. They continue to be ambitious and aspirational: to resolve flood, erosion, and water quality problems at a very high level. Since 2001, substantial progress has been made in meeting these goals as shown in Table EX-7 and 11.2-1 for capital projects, with additional key gains made with programmatic and regulatory improvements.

Even with these achievements, many challenges remain. The 2001 Master Plan attempted to broadly quantify potential goal attainment for the cumulative benefits of capital, regulatory, and programmatic solutions. These estimates were acknowledged to be preliminary due to the conceptual nature of the capital solutions and the inherent difficulty in estimating a numeric benefit for many of the programmatic and regulatory solutions. Estimates were, of course, limited to the 17 watershed areas studied in Phase 1.

This present Master Plan update reviews these estimates and makes recommendations about potential next steps. With 14 additional years of direct implementation experience and a doubling of watersheds to study, estimation of goal attainment has evolved considerably. The goals for the three watersheds missions (see Table 2.4-1) remain unmet, which is expected given the magnitude of the challenges facing Austin both in 2001 and today. Table 11.1-1 presents the status of selected, core Master Plan objectives.

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Table 11.1-1 Status of Selected Master Plan Objectives

Selected Objectives (from Table 2.4-1)	2015 Status
FM1. Reduce the depth and frequency of flooding for all 100-year floodplain structures.	4,545 structures remain in the 100-year floodplain within the City of Austin full purpose jurisdiction*
FM2. Reduce the depth and frequency of flooding on all roads in the 100-year floodplain.	2,207 structures are inundated in a 100-year design storm within the City of Austin full purpose jurisdiction
FM6. Reduce the depth and frequency of local flooding for buildings.	2,085 citizen complaints remain for structure flooding in localized systems
EC1. Repair current erosion that threatens habitable structures and roadways (Type 1 sites).	5 Type 1 erosion problems remain
EC2. Repair current erosion that threatens properties, trees, fences, drainage infrastructure, parks, hike and bike trails (Type 2 sites).	153 Type 2 erosion problems remain
WQ1. In local creeks, achieve or exceed Good (≥ 64) Environmental Integrity Index (EII) scores.	53 of 118 EII Reaches have an overall condition score below Good

** This total reflects property buyouts completed as of August 2016. All other data will be updated in the next annual update.*

Much work clearly remains to be done to meet the goals and objectives for all three missions. The technical feasibility of reaching each objective is, however, different for the water quality mission than the flood mitigation and erosion control missions. Potential solutions are theoretically possible for all creek flood, local flood, and erosion problems—but come at a significant financial and/or community cost. Solution implementation and goal attainment are thus limited by cost and community support, not technical constraints.

For water quality goal attainment, the outlook is less clear and much less quantifiable. Water quality problems are inherently multidimensional, complexly synergistic, and emanate from innumerable sources (hence the term “nonpoint source” pollution which describes them). Austin’s EII measuring system tracks 27 different categories alone, many of which themselves have additional subcomponents. Water quality goal achievement starts with achieving an EII rating of Good for all of our creeks. Just under half (45%) of the 118 sampled EII reaches are below the goal condition of Good. Goal attainment would presumably be accomplished by addressing a sufficient number of these 27 subcomponents. Unfortunately, addressing one or even several of these does not necessarily result in goal attainment. And, some of these elements are problems for which feasible solutions have not yet been found. (This fact underscores the imperative to prevent water quality degradation in the first place, which is the objective of many of Austin’s water quality regulations and WPD programs.)

To help address this challenge, Section 7 presents nine water quality problem categories for which solution categories are identifiable. To repeat, these are: Toxins in Sediment, Litter, Bacteria from Animals, Sewage, Nutrients (Non-Sewage), Construction Runoff, Poor Riparian Vegetation, Unstable Channels, and Altered Hydrology. This plan asserts that if specific problematic elements

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are addressed, then a meaningful portion of the problem for individual stream reaches will be also addressed, thereby assisting with goal attainment. However, unlike with creek flood, local flood, and erosion control, it is not as clear that technically feasible solutions can be found in all instances for these problems. A second look at the goals and objectives of all missions is warranted and recommended and will be the focus of the next Master Plan update.

In the 2001 Master Plan, an attempt was made to broadly quantify potential goal attainment for the creek flood, erosion, and water quality missions for the Phase 1 watersheds. Figure 11.1-1 presents this original estimate, which was based on available, conceptual-level solutions data, such as flood detention ponds, floodplain buyouts, bank stabilization projects, and water quality ponds. The benefits of certain programs and regulations were also included where estimating benefits was deemed reasonable.

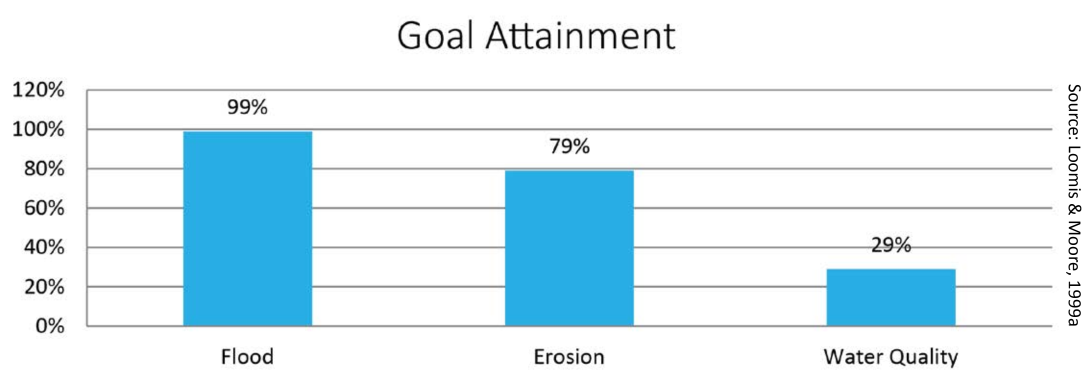

Figure 11.1-1 Generalized Goal Attainment Results from the 2001 Master Plan

The 2001 Plan showed the high potential to address creek flooding and erosion problems to meet the associated goals (99% and 79%, respectively). As noted above, this continues to be the case. At least in theory, essentially all flood and erosion problems can be solved if sufficient resources and community support are available. However, from a practical standpoint, it may also be acknowledged that such resources and support are not infinite. Expected timelines for problem resolution, cost, and impact on communities are required. This evaluation is not available at this writing and thus represents a major recommendation for the next update of this Master Plan. Such an evaluation should also be done in conjunction with a review and refinement of mission goals and objectives.

The 2001 Plan expressed concern for the relatively low (29%) goal attainment for water quality protection. We do not currently have an updated estimate on potential goal attainment for this mission, but we are working to build SWAT models to model hydrology, pollutant loads, and potential solution effectiveness. When available, this information will be used to evaluate our estimation of goal attainment, and will be included in a future update of the Master Plan.

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While the 29% attainment estimate is not necessarily reliable,[1] it is still instructive to review the reasons that the 2001 Plan showed such a low level of goal attainment. We continue to agree that it will be a challenge to meet water quality goals. The first factor cited was the limited amount of undeveloped land available in the urbanized areas suitable for regional water quality retrofits. This continues to be a barrier today, with Austin's rapid urban expansion and infill continuing unabated. At the time of the original 2001 Master Plan, Austin had approximately 669,000 residents. In 2015, it had an estimated 900,000 residents—an increase of 34% of this period,[2] which has been accompanied by sharp increases in property values and fewer vacant tracts of land remaining on which to locate large-scaled water quality retrofits. While partnerships with private or other public development (e.g., TxDOT) have proven to be successful since the 2001 Plan, regional ponds can likely only address a fraction of the remaining developed areas that lack water quality controls.

The second factor cited in 2001 limiting water quality goal attainment was the lack of water quality regulation or mitigation for new development in areas outside the City of Austin's jurisdiction. Notably, 72% of the Barton Springs Zone (BSZ) is located outside of Austin's jurisdiction and beyond Austin's direct control. (A similar dynamic exists for Lake Austin and Lake Travis, which are greatly influenced by other jurisdictions upstream of Austin.) With respect to this concern, much progress has been made since 2001 to address future water quality in the Barton Springs Zone. The most direct action has been the permanent preservation of significant amounts of land through fee-simple purchase or conservation easement. Many of these properties are located outside of Austin's jurisdiction. This remains one of Austin's most important tools in the long-term protection of the BSZ (see CIP recommendations below).

Additionally, in 2005 Austin officially supported the Regional Water Quality Protection Plan for this key area (Naismith Engineering, Inc., 2005).[3] The plan included recommendations for development restrictions and the use of best management practices that, if implemented by participating entities, would provide a significant increase in the protection provided to the aquifer, and would provide a positive impact to goal attainment in the six contributing watersheds. Some headway has been made since the Plan's completion with the adoption of new, stricter water quality regulations for Dripping Springs and actions by Hays County to permanently protect conservation lands. A more

[1] The method of calculation is no longer current (it was not tied to EII factors, for example, and WPD no longer uses nor supports the 2001 GIS-based model developed by UT) and the types of controls proposed for goal attainment are no longer the same as they are today. An example would be the focus in 2001 on regional wet ponds for water quality. While we continue to consider wet pond retrofits, they have significant locational limitations (many of the proposed conceptual designs from 2001 proved infeasible and/or actually might have led to counterproductive function), maintenance cost, and water use concerns that make them less likely to constitute the major role they played in the 2001 Plan.

[2] City of Austin. Austin, Travis County, and Metropolitan Austin population history and forecast - 1940-2040, https://www.austintexas.gov/sites/default/files/files/Planning/Demographics/austin_forecast_2015_annual_pub.pdf, accessed September 2015.

[3] Participants in the development of the plan included The Barton Springs Edward Aquifer Conservation District, the City of Austin, the City of Dripping Springs, Hays County, Travis County, the Hays Trinity Groundwater Conservation District, the City of Buda, the City of Kyle, the City of Rollingwood, the City of Sunset Valley, and the Village of Bee Cave.

complete assessment of the continuing level of threat to the six contributing BSZ watersheds and Barton Springs is not available at this time. Completion of such an analysis is recommended for a future update of this Master Plan.

Finally, the 2001 Plan recognized the then-emerging concept of green stormwater infrastructure (GSI) controls such as rainwater harvesting, rain gardens, enhanced landscaping, and soil amendments.[4] It noted that these controls might be deployed extensively throughout a developed watershed to collectively have a positive impact on the overall water quality of a watershed. GSI controls, however, do not address the full range of the nine water quality problem types tracked in this Master Plan. So, even if successful for altered hydrology or toxins—or perhaps even litter, bacteria, and nutrients— they still would not likely address sewage, construction runoff, poor riparian vegetation, or unstable channels. Since the 2001 study, much progress (see Sections 9 and 10) has been made to make such green stormwater options available for use. And a study is underway at this writing in the Brentwood neighborhood to investigate a decentralized GSI approach to reduce peak flows and runoff volumes to existing stormwater conveyance systems to potentially reduce or eliminate the need for a system-wide upgrade (see Section 10.3.3). This study initiated by the Green Infrastructure Team, seeks to determine the level of benefit to the flood goals that GSI techniques can provide. As mentioned above, the degree to which such controls could address water quality and local flood missions (among others), as well as their financial feasibility, is still under study and not available for this present report. But it certainly offers hope of a multi-mission solution that might address seemingly intractable challenges for meeting water quality goals.

To conclude, this present Master Plan update presents comprehensive changes in the way that watershed problems are studied and prioritized, and solutions proposed; the original 2001 watershed goals and objectives remain unchanged. But a review and potential adjustments is potentially warranted. The next updated to this Master Plan will review and refine the goals and objectives of all three missions, as well as the common goals.

11.2 Implementation Planning

Successful implementation of proposed watershed solutions relies heavily on the availability of sufficient resources, which in turn relies on public input and support. Public hearings and other extensive interactions with boards and commissions were held to review and present the original 2001 Master Plan and obtain public input. Since that time, capital projects and program enhancements have been implemented as funding is approved through the City's annual budgeting process, special bond elections, or other funding allocations. Short- and long-term implementation

[4] It also cited Low Impact Development (LID) designs as an approach, but this is a more realistic approach for new "greenfields" development rather than a set of tools to address existing water quality problems.

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plans are developed based on these funding decisions. Regulatory changes proceed through the appropriate public input process for development of final language, and then through the public review and adoption process.

11.2.1 Capital Projects

When funding is available, policy decisions must be made regarding the implementation of capital projects. This Master Plan presents the different prioritization processes used by each mission. Several included ranking factors such as cost-benefit, sustainability, and neighborhood impacts. But for all, a "needs-based" approach was selected (with the support of the Citizens Advisory Group and approved by City Council in 2000) to prioritize WPD recommendations for future project funding. A needs-based approach simply means that the worst problem areas—where the needs and risks are greatest—will be considered first for project implementation.

Problem area severity ratings for the flood, erosion, and water quality missions form the basis for the priority designation for capital project implementation. Often, projects that fix these "worst" problem areas are very expensive. Final implementation decisions have to consider available resources. Some high-priority but costly solutions may have to be delayed if funds are not available. This may result in less expensive projects that are lower on the priority list being implemented first based on availability of funds. Project implementation is also affected by the source of the funding. Certain sources of revenue, such as the Regional Stormwater Management Fund (RSMP) or the Urban Watersheds Structural Control Fund (UWSCF) are targeted for specific missions and are limited geographically as to where their revenues can be spent. Still other projects may proceed based on "opportunity" considerations where land donations, grant funding, or cost sharing with other City, private, or other governmental (e.g., TxDOT) projects reduce costs for WPD.

A major tenet of this Master Plan is to implement sustainable watershed protection strategies that integrate the Flood Mitigation, Erosion Control, and Water Quality Protection missions. In the past, a single-mission approach caused unanticipated and negative impacts to other missions. Where possible, the WPD Mission Integration and Prioritization (MIP) team, described in Section 10, looks for opportunities to implement multi-purpose, integrated projects designed to maximize watershed benefits. At a minimum, each potential project is evaluated and designed to avoid adverse impacts to other missions as further described below. It is through the MIP process that integrated capital project solutions are identified and implemented.

Finding a balance between fixing current problems and preventing future problems is essential to meeting WPD goals. Regulations alone cannot prevent all future problems. As a result of state legislation, many new developments will not be subject to existing, let alone new, regulations. Results from the Water Supply Suburban Watershed Report (City of Austin, 1999) provided a

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clear indication of the large number of exemptions and "grandfathering" to older regulations that are outstanding within the remaining undeveloped lands within and around Austin. Capital solutions will be a necessary part of addressing future problems.

WPD continues to actively work and partner with other City departments whose missions also affect the health and safety of our waterways, such as Austin Water, Parks and Recreation Department (PARD), Austin Transportation Department, Public Works Department, Planning and Zoning Department, and the Development Services Department. Many of these departments have projects within or adjacent to the waterways that impact the stream corridor and WPD mission goals. Some are involved in long-term planning projects that also offer potential for integration of missions and co-benefits. When acquiring land, whether for conservation easements or future capital solutions, WPD seeks opportunities to pursue joint funding whenever possible for stream corridor restoration and greenbelt establishment. The relatively recent creation of the Capital Planning Office provides a citywide structure that enhances coordination opportunities.

New recommendations to improve WPD's capital planning include creating a database to manage the WPD MIP Integration Process. This will allow better retrieval of data, as well as improved project status tracking. Staff is investigating various software methods to achieve this goal. Improvements in our ability to do effective long-term planning would also be beneficial. As Watershed Profiles are developed to include all missions, these will be a useful tool to assist in this effort (see Appendix C). The current City budget process includes development of a five-year plan. WPD's ability to effectively plan for this timeframe has improved, as problem score methodologies and supporting technical studies have progressed greatly in the past five years. The updates presented in this Master Plan, coupled with the ongoing effort to obtain more accurate data for local flood problem scores, should greatly assist our ability to develop effective long-term capital plans. Pursuing the data-driven methodology for local flooding (use of technical models to supplement citizen complaint data) will assist WPD in making financially sound decisions regarding which infrastructure is in the greatest need of repair. Continuing to work with the City's Capital Planning Office to distinguish between problem-score based local flooding and infrastructure asset management needs will help to prioritize projects and identify appropriate funding sources. A continued lack of a more complete understanding of the magnitude and specifics of our assets maintenance liabilities—the cost to rehabilitate or replace aging storm drainage and pond infrastructure—remains a key challenge; see Recommendations section below for more discussion of the need for an Assets Management Plan.

Competition for funding with limited resources will likely continue over the long term, emphasizing the need for prioritization of spending coupled with identifying cost-sharing opportunities wherever possible. WPD has developed joint-funding categories in its annual CIP appropriation plan for citywide priority projects and participation with developers. Currently the only prioritization system

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in use by the department is based on the mission problem scores, which are not always the only elements that should be taken into consideration for the selection of citywide priority and developer participation projects. To ensure that the most effective projects are selected, WPD is currently developing a prioritization system in coordination with the Capital Planning Office that couples the mission problem scores with other key factors, including implementation of neighborhood and small area plans, cost sharing with public and private partners, as well as supporting citywide goals expressed in the Imagine Austin Comprehensive Plan.

Watershed Protection funds capital projects through a variety of funding sources:

1. Drainage Charge
2. Regional Stormwater Management Program (RSMP)
3. Urban Watersheds Structural Control Fund (UWSCF)
4. Voter Approved Bonds and Certificates of Obligation
5. Grants (e.g., federal monies from FEMA or the Corps of Engineers)
6. Tax Increment Financing (TIF)

The primary source for annual capital funds is the **Drainage Charge**. This revenue source is collected in monthly utility bills to Austin residents and commercial businesses. The charge is based on both the amount and percent of impervious cover on a property. Other sources of funding include two systems that offer developments to make a payment-in-lieu of constructing onsite stormwater controls: the **Regional Stormwater Management Fund (RSMP)** and the **Urban Watersheds Structural Control Fund (UWSCF)** (see 9.4.6.6 Payment-in-Lieu Alternatives).

Monies collected for the **RSMP** are watershed specific: funds must be spent within the watershed in which they are collected on projects that improve flood conveyance or reduce flood risk for either the creek or localized system. Examples of some of the projects that these funds have contributed to construction of include Bull Creek Lakewood Drive Low Water Crossing Slaughter Creek David Moore Drive Low-Water Crossing, and Williamson Creek Covered Bridge Low-Water Crossing. A project currently in process with use of these funds is the Slaughter Creek Old San Antonio Road Low-Water Crossing.

A second source of payment-in-lieu funding is the **Urban Watersheds Structural Control Fund (UWSCF)**. This ordinance provision allows for payment-in-lieu of onsite construction of water quality controls in Urban watersheds. This funding must be spent with the Urban watersheds on projects that improve water quality. Examples of projects to which these funds have contributed include the Shoal Creek Central Park Wet Pond, Blunn Creek St. Edward's Wet Pond, Shoal Creek Arbor Walk Biofiltration Pond, and the East Bouldin One Texas Center Rain Gardens. Projects currently in process with use of these funds include the Shoal Creek Pease Park Riparian Restoration Improvements and the Waller Creek Reznicek Field Water Quality Retrofits. Funds from these sources are generated

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in relatively small amounts, but they collectively provide key revenue for capital projects. They are typically used to supplement other funding sources, such as partnerships with developments, funding from the Drainage Charge, or both.

Debt from **voter-approved bonds** and **Certificates of Obligation** (COs) is also an important source of funding for Watershed Protection capital projects. Unlike the Drainage Charge, which is collected monthly and provides regular, annual funding, voter approved bonds and COs have been obtained more intermittently to fund larger projects. Since the 2001 Master Plan, voter approved bonds have been authorized for watershed projects in the 2006 and 2012 bond programs and COs in multiple years. COs have been used for projects such as the Waller Creek Tunnel and home buyouts in flood prone areas.

The Watershed Protection Department seeks significant additional funding from **grants** whenever possible to supplement its other funding sources. WPD has successfully obtained federal grant money from the Federal Emergency Management Agency (FEMA), primarily to supplement funding for the creek flood home buyout program. The Lower Onion Creek Flood Mitigation Buyout Project, Williamson Creek Bayton Loop Flood Mitigation Buyouts, and Woodview Mobile Home Park Flood Mitigation Buyout Project have all received key grant funding.

Funds from Tax Increment Financing (TIF) revenue is the final form of funding used by the Watershed Protection Department. TIFs are a method to use future gains in property taxes to subsidize current improvements, which are projected to create the conditions for the projected tax gains. The completion of a public or private project often results in an increase in the value of surrounding real estate, which generates additional tax revenue. Sales tax revenue may also increase and jobs added to the economy, although these factors and their multipliers usually do not influence the structure of a TIF. The Waller Creek Tunnel project is the sole example to date of a TIF used for watershed solutions in Austin. The City Council created the Waller Creek Tax Increment Financing Reinvestment Zone No. 17 in June 2007 to finance the construction of flood control improvements along lower Waller Creek. The City will dedicate 100% of its tax increment revenue to the project. The City's funding partner, Travis County, will dedicate 50% of its tax increment revenue from the TIF district. TIFs are limited in use to areas that would see a significant increase in real estate value as a result of the capital improvement project. In terms of capital projects for Watershed Protection, Waller Creek may be a unique opportunity for the use of TIF revenue because of this requirement. While the majority of funding for the Waller Creek Tunnel originated from the TIF, additional funding was also provided by voter-approved bonds, Certificates of Obligation, and the Drainage Charge.

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11.2.1 Capital Project Accomplishments

Since the Watershed Protection Master Plan's adoption in 2001, the Watershed Protection Department has made significant progress in meeting the Plan's goals by implementing over 100 capital projects. 11.2-1 below presents some of the key indicator benefits of projects implemented since 2001 for all three missions. Note that in many cases, these numbers are undercounts, based on available data, to be conservative. A future update of this Master Plan will more completely assess these benefits.

Table 11.2-1 Capital Project Benefits by Mission (2001 - 2015)

Mission	Benefits*

Creek Flood	• Over 1,300 total structures with reduced creek flood risk [†]
	    • Over 500 structures with reduced flood risk via a structural solution
	    • Over 800 parcels removed from flood risk with property buyouts [†]
	• 10 low-water crossings upgraded

Local Flood	• Over 11 miles of pipe replaced • Over 350 structures with increased local flood protection
Erosion Control	• Over 4.6 miles of streambank protected • 29 parcels removed from erosion risk with nonstructural solution (property buyouts)
Water Quality Protection	• Over 1.5 million pounds of total suspended solids (TSS) removed per year • Over 7,000 acres land area treated by structural controls

** Estimates represent available data reported in the City's capital project reporting database and does not include benefit information for all completed projects since 2001. Efforts to append this data are underway and will be reported in future Master Plan updates.*

[†]These totals reflect property buyouts completed as of August 2016. All other data will be updated in the next annual update.

To give an idea of more specific projects and details, Table 11.2-2 below presents a sample of key capital projects and their accomplishments.

Table 11.2-2 Key Projects (2001 - 2015)

Project Name	Benefits
	Flood Mitigation Projects
Walnut Creek Crystalbrook Flood Control Project	• Provided 100-year flood protection for 175 homes with floodwall • Preserved 3,500 linear feet of natural stream channel, which scored in the highest categories for Aquatic Life Support and Non-Contact Recreation • Preserved more than 1,000 protected trees over 19 inches in diameter • Promoted use of green stormwater infrastructure best practices by allowing their placement within buffer (with restrictions)

Onion Creek Property Buyouts (ongoing)	• Acquired a total of 731 flood risk properties between 1999 and August 8, 2016
	    • 477 in the U.S. Army Corps of Engineers Project Area
	    • 254 outside the U.S. Army Corps of Engineers Project Area
	• Will restore significant natural floodplain area

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Table 11.2-2 Continued

Project Name	Benefits
Carson Creek Hoeke Lane Low Water Crossing	• Elevated and widened road at creek crossing to provide safe access to a residential neighborhood • Installed 14 culverts • Provided sidewalk/installed curb and gutter
Blunn Creek Long Bow Storm Drain Improvements	• Installed 6,200 linear feet of stormdrain • 25 homes benefited from reduced flooding • 6 locations of street flooding alleviated
Shoal Creek Allandale Storm Drain Improvements	• Installed 5,900 linear feet of storm drain • Project addressed 15 building complaints, 2 yard complaints, and 26 street complaints
Erosion Control Projects	
Fort Branch Reaches 6 & 7 Channel Rehabilitation	• Stabilized 1,600 linear feet of streambank • Installed new span bridge • Buyout of 5 homes in 25-year floodplain • Installed 700 linear feet of storm drain
Shoal Creek NW Park to Foster Lane Erosion Stabilization	• Stabilized 2,800 linear feet of streambank • Secured eroding NW Park Detention spillway • Secured exposed and threatened wastewater infrastructure
Water Quality Protection Projects	
Williamson Creek Lundelius-McDaniels Water Quality Pond	• Provided treatment for over 200 developed acres in Barton Springs Zone • Removes over 28,000 lbs of total suspended solids (TSS) annually • Removes over 128 lbs of nitrogen annually
Barton Springs Zone Water Quality Protection Lands	• Acquired 17,513 acres in conservation easements on private properties • Acquired 10,841 acres in fee simple public lands • Manage public lands to restore prairie-savanna ecosystems and healthy riparian corridors
Boggy Creek Oak Springs Water Quality Pond	• Provides treatment for 182 acres • Removes 40,000 lbs total suspended solids (TSS) annually • Reduces chemical oxygen demand by 40% • Installed curb and gutter

11.2.2 Operating Programs

As discussed in Section 10, operating program enhancements were defined based on a level of service analysis. This analysis resulted in the identification and initial prioritization of needed WPD program enhancements. While some identified program enhancements do not require funding to implement, others will require additional funding approval through the City's annual budgeting process. WPD proposes budget enhancements incrementally as Council considers potential increases in the Drainage Charge.

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Significant progress has been made to implement the 2001 Master Plan program recommendations. Program enhancements that improve the level of service often take multiple years to implement and are ongoing. Other enhancements have been completed to improve coordination between missions and increase program efficiencies to help achieve goal attainment. Insufficient funding levels have proven to be the main obstacle in fully implementing all of the program recommendations. Appendix D summarizes the status of the 2001 Master Plan program recommendations. Table 11.2-3 and 11.2-4 include recommendations for additional program enhancements developed through the protocols discussed in Section 10. These recommendations have been broken into two groups. The first group of recommendations require additional department and/or interdepartmental coordination, but no additional resources.

The second group of recommendations requires significant additional resources. Notably, most of these program recommendations for additional resources are expansions upon those made in the 2001 Master Plan. Growth in Austin's population, land area, and new infrastructure—as well as 14 additional years for already-aging infrastructure—have made it difficult for WPD to keep pace with expected levels of service in some key areas.[5]

Table 11.2-3 Proposed Program Enhancements Requiring Increased Coordination (2015)

Department and/or interdepartmental coordination is needed, but no additional resources are required.	
Program Name	Proposed Enhancement
Flood	
Stormwater Pond Safety Program	Clarify and potentially revise local criteria to regulate dams that fall below TCEQ-defined dam size thresholds.
Water Quality	
Surfacewater Evaluation (* included in Imagine Austin Comprehensive Plan work programs)	Identify and implement best approaches to provide small-scale, green infrastructure water quality projects on public property consistent with the Imagine Austin Green Infrastructure Priority Program.*
	Work with regional intergovernmental partners to develop sustainable wastewater management practices in the Barton Springs Zone.
	Continue to collaborate with Austin Water to implement the Sustainably Manage Our Water Resources (SMOWR) Priority Program for Imagine Austin (e.g., assessment of water quality impacts of application of reclaimed water near waterways and evaluation of environmental impacts of implementation of potential new water supply options).*

[5] A good example of this change is that of Stormwater Pond Maintenance. The 2001 Master Plan noted the following in its recommendation: "Current budget measure is 250 of the 480 ponds are maintained annually." As of September 2015, the number of ponds directly maintained by WPD Field Operations staff is over 890. This represents an increase of 85% in the 14-year period.

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Table 11.2-3 Continued

Department and/or interdepartmental coordination is needed, but no additional resources are required.	
Program Name	Proposed Enhancement
Integrated	
PIO / Community Services	Target flood safety outreach to neighborhoods subject to flooding. Develop outreach to promote education programs for real estate agents, appraisers, and insurance agents.
Watershed Education	Increase resources to improve the review, communication, and follow-up with new developments that require Integrated Pest Management (IPM) plans. Improve interdepartmental planning on pesticide use. Consolidate IPM plans into one user-friendly, citywide plan.
Review and Inspection of Development	Continue to develop and implement training for consistency in code application and enforcement amongst staff. Evaluate staff levels as development permit requests increase to ensure adequate staffing for work load.
Data Management	Increase database coordination to publish on a departmental level project planning datasets and databases to enhance the identification of critical and capital needs.
	Coordinate with Development Services to scan general permit drawings for review on Amanda.
	Generate a departmental plan for DIG update of how new data from modeling/engineering studies or construction projects can be integrated into the DIG database.
Open Waterway Maintenance	Continue the implementation of a protocol in which representatives from creek flood, erosion and water quality attend the monthly open waterways meetings and are advised of all channel maintenance activities.
	Continue to revise sustainable maintenance practices for easements and channels in City parks, coordinating with Floodplain Management, to not routinely mow or extensively maintain these areas, unless required for flood conveyance. Develop a management plan for these resources with PARD.

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Table 11.2-4 Proposed Program Enhancements Requiring Significant Additional Resources (2015)

Entries marked with "†" were also identified as requiring additional resources in the 2001 Master Plan.

Program Name	Proposed Enhancement
Erosion	
Erosion Repair & Open Waterway Maintenance	Add additional resources to increase the number of erosion projects and channel maintenance completed on a yearly basis to cost-effectively address the large backlog of open channel drainage infrastructure problems. †
Flood	
Local Flood Hazard Mitigation	Add additional resources to increase the rate of production of preliminary engineering studies, design plans, support modeling, and flood data analysis to identify and prioritize infrastructure improvements and provide design information to the public. †
Field Engineering Services	Increase level of investigations and short-term solutions for drainage issues not already associated with long-term CIP problem areas and more effectively respond to drainage-related service requests (e.g., 3-1-1 calls). †
Infrastructure Inspection	Increase level of TV inspections of storm drain infrastructure that has exceeded its lifetime; will better enable prioritization of problem areas for repair and replacement and enhance coordination with other City projects. †
Storm Drain Cleaning	Add additional resources to enable an increase in the number of inspections performed and the miles of pipeline cleaned and to help keep pace with the expanding service area resulting from annexations. †
Storm Drain Rehabilitation	Add additional resources to increase the rate of repair and replacement of the City's drainage infrastructure to cost-effectively address the large backlog of storm drain rehabilitation problems. †
Integrated	
Stormwater Management	Study possible approaches to address inspection of pond facilities to ensure compliance with inspection frequencies required by the Land Development Code and to keep pace with newly constructed and newly annexed facilities. †
Pond Maintenance	Study possible approaches to address maintenance of pond facilities to ensure compliance with maintenance requirements of Austin's TPDES permit and to keep pace with newly constructed and newly annexed facilities. †
Green Infrastructure Maintenance	Study and implement a cost-effective approach to care for green stormwater infrastructure and other related WPD responsibilities (e.g., maintenance of City-owned natural parcels, erosion and restoration projects, etc.).
	Establish a dedicated Trash and Debris team to coordinate with existing contractual to coordinate cleanups with Keep Austin Beautiful, PARD, APD and civic groups to focus on high need areas. †
	Coordinate with other City departments to evaluate management options and designated uses of land acquired through flood and erosion property buyouts.

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In addition to the program specific recommendations included in these tables, WPD faces a challenge to develop an asset management plan to address aging drainage infrastructure. This challenge is not unique to WPD, and is an issue that is receiving citywide attention by management. It is also a national challenge faced by virtually every US city. Efforts of the Capital Planning Office, discussed in Section 10.4, focus on identifying the costs for asset management related needs and evaluating potential funding sources for the entire City.

Asset management is a process of ensuring proper maintenance, rehabilitation, and replacement of infrastructure assets. A major focus is that of extending infrastructure life at the lowest possible cost. Our drainage infrastructure includes storm drain inlets, pipes, manholes, drainage ditches, natural waterways, and water quality and flood/erosion control ponds. With the completion of the DIG anticipated in the next few years, which spatially locates these improvements and includes attribute information regarding size and condition, WPD will need to place an emphasis on development of an asset management plan to identify a strategy and implementation goals to address the long-term needs of this system.

11.2.3 Regulations

The 2001 Watershed Protection Master Plan recommended numerous regulatory improvements. Appendix E presents a summary of the status of the 2001 Master Plan regulatory recommendations. Progress has been made in addressing most of these: of 29 total recommendations, 27 have been completed.[6] And for the two original recommendations not completed, WPD does not recommend either for further action.[7]

With much of the past identified work accomplished, this Master Plan now narrows its recommendations to two regulatory changes. These proposed regulatory changes are planning-level recommendations. Each proposal will need to be further vetted by staff and will require drafting of Land Development Code and/or Environmental and Drainage Criteria Manual language. Code changes require public hearings and review by the appropriate City boards and commissions (typically the Environmental and Planning Commissions for watershed-related code changes) and final review and approval by the City Council. Proposed rule (criteria) changes are subject to stakeholder review and a public review period. This includes proposed changes to criteria manuals. After stakeholder review, the rule is posted for public comment prior to final adoption. Table 11.2-5 presents these enhancements.

[6] Note: work continues on two of these completed items to formalize the improvements in the Drainage Criteria Manual: (1) Drainage Design Criteria (improved channel design) and (2) Stormwater Detention Design Criteria for Volume Control (a.k.a., volumetric detention). See Appendix E for more details.

[7] See Appendix E for these two items: (1) a **Golf Course Management Plan** is no longer considered necessary at this time due to other regulatory improvements to prohibit managed golf course areas within Critical Water Quality Zone creek setbacks. And (2) changes to **Effluent Irrigation Standards** for wastewater application are no longer possible as these regulations are now the sole purview of the State of Texas.

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Table 11.2-5 Proposed Regulatory Enhancements (2015)

Proposed Regulation	Regulatory Enhancement
Improved integration of Landscape and Green Stormwater Infrastructure Requirements	Much progress has been made toward offering new Green Stormwater Infrastructure options and requiring some level of integration of on-site water management with commercial landscapes (See "Landscape Modifications and LID Design" entry in Appendix E). However, in response to the ongoing drought; future challenges with climate change; a strong recommendation by the Austin Water Resource Planning Task Force; and growing, positive examples offered by other US states and municipalities, additional actions are warranted and practical to more beneficially re-use stormwater on-site for both environmental protection and water conservation.
Improved Flood Mitigation Requirements for Redevelopment Projects	Redevelopment of existing development currently requires the retrofitting of water quality controls to improve water quality. However, equivalent requirements for flood mitigation are not required: projects, many of significant scale and impact, can be currently built with no improvement to address existing, downstream flooding problems under typical circumstances. Consideration should be made to provide some level of flood mitigation for such projects. Any proposed change would have to provide flexibility to balance the community's interest in revitalizing existing centers and corridors per Imagine Austin goals.

The CodeNEXT Land Development Code rewrite that is underway at the time of this writing. It offers the best means to address these recommended items. As a part of this effort, WPD staff led the Green Infrastructure Working Group in 2015 to help identify critical issues and provide recommendations on potential code changes. Modeled on the Watershed Protection Ordinance (WPO) stakeholder group, this group brings together the public, members of the CodeNEXT citizen advisory group, and staff from multiple departments to examine how the Land Development Code can be modified to achieve the Imagine Austin goals of integrating nature into the city, sustainably managing our water resources, and creating complete communities. The input from this stakeholder process is being incorporated into staff recommendations for CodeNEXT.

11.2.4 Procedures

Table 11.2-6 below presents a summary of proposed revisions to departmental procedures.

Table 11.2-5 Procedural Recommendations (2015)

Proposed Revision	Procedure Enhancement
Work with other departments to develop Green Streets policy to implement watershed protection goals	The City Council adopted a Complete Streets Policy in June of 2012. The policy includes a directive to "seek opportunities to integrate best practice Green Street principles, features, and metrics adapted to Austin's climate." Green Streets has been defined as encompassing three elements – landscape features (street trees and other vegetation), stormwater management features, and sustainability (e.g., materials, waste minimization, etc.). With regard to stormwater management, a particular focus is on the placement of features in the public right-of-way that integrate stormwater treatment with landscaping (e.g., rain gardens). Such features are increasingly being incorporated into City street reconstruction and traffic calming projects.

11.3 Flood Mitigation Task Force (FMTF)

On June 6, 2014, the Austin City Council passed Resolution 20150604-044 to create a Flood Mitigation Task Force (FMTF). The resolution laid out a broad scope of work to "gather information and develop recommendations related to citywide and area flooding and its impacts to property, public safety, and City finances, with an emphasis on flood mitigation solutions and funding options." Composed of two members each from Austin's Mayor and Council members, the 22-member group met from September 22, 2015 to May 16, 2016. The FMTF formed three Working Groups (Operations and Maintenance; Capital Improvements; and Buyouts and Floodplain Variances) and produced a Final Report for Environmental Commission and Council consideration. The FMTF concluded its work with its presentation to Council on May 19, 2016. WPD provided support and assistance as requested throughout the period.

11.3.1 FMTF Final Report: Findings and Recommendations

The FMTF Final Report presents over 200 recommendations on eleven main topics:

1. Mitigation and preparedness strategies
2. Property buyouts and floodplain variances
3. Structure and use of the adopted Drainage Charge
4. Costs and factors affecting affordability and equity
5. Public education and outreach to keep the public safe
6. Master planning, regulations, and green infrastructure
7. Identification of funding sources
8. Best Practices in peer cities
9. Onion Creek Flood Study comments
10. Collaboration with Environmental Commission
11. Other partnership opportunities

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Most of the recommendations were for the Watershed Protection Department, with others for other City of Austin departments, the Austin Independent School District, and other entities.

11.3.2 FMTF Implementation and Next Steps

WPD staff evaluated all FMTF Final Report recommendations for impact, feasibility, and cost of implementation. WPD recommended a number of budget changes to the proposed Fiscal Year 2017 City budget that align with key FMTF recommendations. Key themes include the need to provide additional Field Operations capacity for maintenance and repairs of waterways and infrastructure, plus additional resources for flood education. Full implementation of the FMTF recommendations will require a longer timeframe. In July 2016, WPD staff began support of an Environmental Commission subcommittee that will review the Final Report and make its own recommendations for a path forward to achieve the Council's vision with respect to the FMTF Final Report.

11.4 Findings and Recommendations

The following findings were developed based on information gathered in each step of the Master Plan, including goal development, technical assessments, and integrated solution development. Development of goals establishes direction for each mission to proceed. Technical assessments provide the data needed to measure watershed problems against watershed goals, and determine where needs are greatest. Integrated solutions development defines which solutions are potentially feasible and provides general cost and benefit information upon which to gauge potential goal attainment. Based on these findings, recommendations were developed to guide WPD on future funding decisions for capital projects and operating programs, and to outline an implementation plan for future regulatory modifications.

11.4.1 Findings

1) Substantial progress has been made since 2001 in addressing flood, erosion, and water quality problems in accordance with the Master Plan goals. For example, over 1,300 structures have been removed from the floodplain, 11 miles of storm drain pipe replaced, 4.6 miles of stream channel stabilized, and over 7,000 acres of developed land treated by water quality structural controls, as presented above in Table 11.2-1.
2) Despite this considerable progress, flood, erosion, and water quality problems continue to be widespread, primarily due to development prior to Austin's protective watershed regulations. WPD must continue to find ways to cost-effectively address these needs and take corrective action to avoid even greater costs if this action is deferred.

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3) The City of Austin is a dynamic and rapidly growing city. Since the original 2001 Watershed Protection Master Plan, Austin has grown from an estimated 669,000 residents to over 900,000 in 2015—an increase of over one-third. This growth has increased the City's urbanized footprint and drainage infrastructure, proportionately increasing the burden to maintain these assets and protect lives, property, and the environment.

4) Over the next 40 years, a range of $1.8 to 2.2 billion[8] in capital funds are required to construct new or improved integrated watershed protection facilities including detention ponds, channel stabilization projects, and other flood, erosion, and water quality controls.

5) Additional resources and funding are needed to provide adequate levels of assets maintenance of Austin's drainage infrastructure; current rates of repair and replacement are not keeping pace with the growing deterioration of the system, and delays in such action only further increases eventual costs.

6) The 2013 Watershed Protection Ordinance addressed the majority of outstanding regulatory recommendations from the 2001 Master Plan. Several additional code and criteria changes are still recommended to address the need for improved on-site infiltration for baseflow, beneficial use of stormwater, and to address flood concerns with redevelopment.

7) Attainment of erosion and flood goals may be technically possible but will require significant funding and community support; the 2016 Flood Mitigation Task Force's Final Report presented many constructive recommendations on this subject.

8) Water quality goals may not be attainable through implementation of solutions presently evaluated in the Master Plan. Limited regional retrofit opportunities in urbanized watersheds and inadequate regulatory controls in areas outside the City's jurisdiction are significant constraints.

9) The Imagine Austin Comprehensive Plan strongly supports watershed and environmental protection elements, including the Watershed Protection Master Plan. It presents specific priority programs to "integrate nature into the city" using green infrastructure and "sustainably manage our water resources."

11.4.2 Recommendations

Continue to implement current successful policies:

1) Develop long-range funding proposals to support solution implementation.

2) Integrate watershed solutions to effectively promote watershed protection goals across all missions.

3) Adhere to the core Master Plan principle that the most severe problems should be considered first for solutions identification and implementation as funding becomes available.

4) Partner with others to achieve watershed protection goals, address challenges across jurisdictional boundaries, and realize economies of scale. Partnerships include those with private development and land owners; federal, state, and local governments; other City departments (e.g., the Capital Planning Office), community groups, and concerned citizens.

[8] The original 2001 Master Plan estimated $800 million for 18 Phase 1 watersheds. The new increased estimate includes both an inflation factor and expands the area considered for potential projects to Phase 2 watersheds.

5) Use Master Plan results to assist in the development of proposed WPD budget increases to fund priority program enhancements.
6) Involve stakeholders at a high level in the comment and review process for all proposed regulatory modifications using the model established by the Watershed Protection Ordinance.
7) Continue Master Planning efforts in Phase 2 watersheds as funding allows, including the development of more site-specific analysis via Watershed Profiles.
8) Support watershed and environmental protection elements in the CodeNEXT process to best implement the vision and goals of the Imagine Austin Comprehensive Plan. These specifically include “integrate nature into the city” using green infrastructure and “sustainably manage our water resources.”

New Recommendations:

9) Develop an asset management plan in coordination with the Capital Planning Office to identify an approach and funding mechanism to address the long-term maintenance of Austin’s aging drainage infrastructure; include an evaluation of an appropriate level of service for drainage repairs and replacements to implement this approach.
10) Refine watershed protection goals based on continued public involvement and experience gained in Austin and from other communities. For example, continue the evaluation of and experimentation with green stormwater infrastructure solutions to attain water quality goals. Consider revisions to water quality goals to reflect additional evaluation and feasibility of solution implementation.
11) Update the Master Plan on a regular basis, such as a five-year cycle, to ensure that up-to-date information is included; maintain the updated Master Plan document and interactive maps with problem scoring and solutions data on the web for public access.
12) Continue to seek ways to implement the recommendations of the 2016 Flood Mitigation Task Force’s Final Report to cost-effectively improve public safety and property protection from flooding.

11.5 Future Master Planning Efforts

The annual Watershed Protection Master Plan Report to the Environmental Commission will continue to be revised to reflect updated information on high priority needs. These updates will include problem score updates for additional Phase 2 watersheds, results of improved modeling efforts, and current watershed conditions.

Environmental Integrity Index (EII) scores are now available for all watersheds wholly or partially within Austin’s jurisdiction. Flood and erosion technical studies have been completed for many Phase 2 watersheds, as reflected in the updated problem scores in sections 4 and 6. Additional studies of the Phase 2 watersheds will continue as funding is available.

WPD will continue to work with the public in developing sustainable watershed solutions for all watersheds in the City of Austin.

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Appendix A

1 Fiscal Year 2015 - 2016 Update

The FY 2015-2016 Update is the first annual update to the Watershed Protection Master Plan document and includes the following changes:

- Updated problem score data to reflect data produced in October 2015 and resulting Priority Problem Areas used in the FY2015-2016 CIP appropriation planning process (Executive Summary, Sections 4-7, Section 10).
- Updated status of watersheds with technical assessments (Sections 4-7).
- Inclusion of updated Creek Flood structure problem scoring methodology (Section 4): In Fall of 2015, the Creek Flood mission updated the structure cluster scoring methodology after identifying several individual structures with severe inundation risk that were not included in the highest scoring structure clusters. Previously, the structure cluster scoring methodology added together the narrative rating value (1 - 5, see table 4.5-2 in Section 4) of each structure within a cluster. The updated methodology sums the total raw score of each structure within a cluster, ensuring that clusters with structures at the most severe flood risk are weighted the most heavily, instead of clusters with the largest number of structures. The result is a more accurate depiction of the relative severity of each cluster and a number of changes in the rankings of structure clusters from the 2015 Master Plan update to this present 2016 Master Plan update.
- Updated information regarding the CodeNEXT effort (Executive Summary, Section 10).
- Updated information regarding the Flood Mitigation Task Force effort from Fall 2015 – Summer 2016 (Executive Summary, Section 11).
- Updated buyout status information (Executive Summary, Section 4, Section 11).
- Updated Findings and Recommendations (Executive Summary, Section 11).

2 Differences between 2001 and 2015 Master Plan

In the 14 years since the 2001 Master Plan was published, WPD has made advancements in:

2.1 General

- The 2015 update introduces data from the "Phase 2" watersheds, expanding the total number of watersheds studied from 17 to 49.
- The 2015 update tracks the current status of the 2001 Master Plan's programmatic and regulatory recommendations, and proposes new recommendations.
- The estimate of capital funds expenditures needed to address watershed problems has been revised from $800 million to $1.2 – 1.9 billion.

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- The 2013 Watershed Protection Ordinance addressed the majority of outstanding regulatory recommendations from the 2001 Master Plan. Several additional code and criteria changes are recommended to address the need for improved on-site infiltration for baseflow, reuse of water for conservation, and to address flood concerns with redevelopment.
- The 2015 update uses improved methodologies to calculate and prioritize problem locations for all missions, which enables improved, more precise decision-making.
- The 2015 update reorganizes and adds a new chapter regarding information management to the 2015 edition (Section 8: Data Collection and Evaluation).
- The approach to the integration of solutions across all three departmental missions has changed (see “Integrated Solutions” below). The 2001 Section 8 on Integrated Assessment was repurposed for Data Collection and Evaluation (see previous) and the new, improved integration approach described in Section 10.

2.2 Creek Flood

- The 2015 edition expands the number of watersheds fully modeled and prioritized from 15 to 28.
- The 2015 edition uses improved modeling techniques and coverage to more precisely estimate potential primary structures and roadway crossings flooded during a 100-year storm event: from 7,000 – 8,000 to 3,021, and from “over 200” to 430, respectively.

2.3 Local Flood

- The 2015 edition has more precise estimates of the quantity of storm drain pipes within the jurisdiction (400 miles to 1,000 miles).
- The 2001 Master Plan refers to an upcoming pilot study for a larger Drainage Infrastructure GIS (DIG) to evaluate storm drain systems in Waller Creek watershed. The 2015 study benefits from the DIG project having completed approximately 80% of this 1,000 mile system.
- The 2001 study included problem area information on 15 complete watersheds and portions of 5 others, calling for modeling to more objectively gauge the problems. The 2015 Plan presents data for 52 watersheds and includes storm drain modeling for 19% of the system for prioritization purposes, targeting older areas of town with the greatest need for local flood solutions.
- The 2001 database of 6,800 citizen drainage complaints has been comprehensively reviewed and updated to reflect 1,368 individual properties; the number was reduced by accounting for multiple complaints at a single address, problems solved/removed from active list, and problems determined to be private (not the public responsibility of the City of Austin).
- Since the 2001 study, local flood has gained the ability to perform video inspections to identify blockages and sections needing repairs.
- Local flood has also added advanced field survey techniques such as the use of GPS and laser survey equipment.

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- This study introduces an intensive case study of the West Bouldin watershed, which examines the flooding consequences of infill redevelopment in an area of old and undersized drainage infrastructure.

2.4 Erosion Control

- With the addition of the Phase 2 watersheds to the study scope, the 2015 update expands the number of reaches studied from 199 to 441. In total, Erosion Assessments have been completed for 29 watersheds (from 17 in 2001)
- The 2001 Master Plan used the Chan Erosion Studies (1997) as the basis for channel assessments for erosion. The 2015 update presents a modified and enhanced Erosion Scoring System based in part on the Chan methodologies, but improved after extensive field and professional experience by WPD staff.
- The 2015 Erosion Scoring System:
  - No longer uses estimates of historic and future channel enlargement (although this 2001 data is retained in Appendix A for reference), and also discontinued the use of Future Reach Stability scoring system.
  - Revised Resource Value scores.
  - Employs a more precise and quantitative methodology for calculating Erosion Site Severity Scores and Reach Problem Scores. Rather than a subjective assessment, these scores now reflect a weighted distribution of geotechnical, surface cover, and planform influence.

2.5 Water Quality

- The 2015 update expands of number of watersheds studied and prioritized from 18 to 49.
- The EII scoring system has evolved and improved. Some categorical components have either been added or dropped. For example, the Channel Stability component has been discontinued because it is redundant with similar measures in Erosion Control scoring system.
- The Problem Scoring System is no longer based solely on EII scores. Ten individual problem scores derived from EII and SWAT subcomponents are now used for prioritization purposes to direct solution implementation.
- Discontinuation of resource values for water quality scoring. (Note: this consideration is under review and a future edition may reintroduce this system.)
- The 2001 future water quality problem scores were calculated using a UT model that is no longer supported by GIS. Going forward, SWAT (Soil and Water Assessment Tool) model results will be used for future water quality scores when final outputs from these models become available.
- Since 2001, the Riparian Restoration Area Identification Program has been added to prioritize restoration projects.

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2.6 Integrated Solutions

- Solutions integration remains a top priority, but the approach has evolved significantly from the original 2001 Master Plan. Experience showed us that in the (few) integrated problem areas identified in the 2001 Master Plan, the best approach was to have an individual mission lead with its highest identified problems and have other missions then study ways to add value—or at least not have the proposed project do harm to another mission. (See the introduction of the MIP Team process in "Solutions Development" below; the MIP Team plays a key role in the ongoing integration of solutions, replacing the original 2001 methodology.)
- In the 2015 update, the Integrated Assessment content has been moved Section 10, Identifying Preferred Solutions.

2.7 Solutions Development

- The 2015 update adds 26 new potential capital solutions, programs, and regulations:

	Flood Mitigation	Erosion Control	Water Quality Protection	Integrated
Capital Solutions	• Underground Ponds	• Grade control	• Integrated Pest Management • Secondary Containment • Good Housekeeping • Design Practices • Facilities Layout • Biofiltration • Vegetative Filter Strips • Non-required Vegetation • Riparian Restoration	
Programs	• Creek Flood Hazard Mitigation • Infrastructure Inspection Program • Waller Creek Tunnel Operations and Maintenance		• Environmental Policy • Water Quality Planning • Groundwater Evaluation • Endangered Salamander Protection • Watershed Modeling and Analysis	• Value Engineering • CIP Coordination • Sustainability
Regulations	• Floodplain Modification Criteria • Stormwater Pond (Dam) Safety	• Erosion Hazard Zone Requirements	• Wastewater Service Extension Requests (SERs) • On-site Sewage Facility Requirements • Urban Payment-in-Lieu of On-Site Controls • Turf and Landscaping Regulations • Void and Water Flow Mitigation • Pollution and Attenuation Plan	• Imagine Austin Comprehensive Plan

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- The 2001 approach distinguished between “rural, developing, and urbanized” watersheds and resulting solutions preferences. The 2015 Master Plan shifts to the regulatory classifications of Urban, Suburban, Water Supply, and Barton Springs Zone watersheds to better correspond to current WPD practice. We defer considerations of targeted problem and solution identification to the individual Watershed Profiles. A possible future addition would be to include a summary table with this information for general interest and consultation.
- The 2001 Master Plan did not directly present specific capital solutions. The 2015 Master Plan presents “Top 20” solutions lists for major capital categories: creek flood structures, creek flood street crossings, local flood, erosion control, and water quality.
- The 2015 update introduces the Mission Integration Prioritization (MIP) Team created to implement the Master Plan. (See discussion of “Integrated Solutions” above.) The MIP Team did not exist at the time of the 2001 Master Plan; its members examine specific technical and benefit-cost considerations for capital project integration, presented only in general terms in the 2001 Master Plan.
- The 2015 update also introduces additional specialty teams created since the 2001 Master Plan: Value Engineering Team, Modeling Team, Data Team, and the Green Stormwater Infrastructure Team.
- The 2015 update expands and changes the original discussion of preferred capital solutions by mission using the experience gained from the intervening years of WPD’s work. WPD continues to move away from “hard” solutions (e.g., concrete armoring, gabions, etc.) to more natural and “green” approaches, which use natural materials wherever possible. For example, gabions are much less emphasized in the 2015 edition. This change was anticipated by the 2001 edition, but now we have much more experience to confirm this approach. However, because site-specific conditions may warrant more conventional practices, these solutions are still included with caveats in the 2015 edition.
- WPD continues to evolve towards smaller-scale, distributed green infrastructure structural solutions for water quality problems rather than large, regional solutions. The 2001 Master Plan’s focus reflects the past preference for regional controls, especially wet ponds. However, the 2001 authors acknowledged that many identified projects from a supporting Master Plan study (Loomis, 1999) were environmentally inadvisable or not feasible due to a of lack of space. But as with the preferred capital solutions, site-specific conditions may warrant more conventional practices, so these solutions are still included with caveats.
- The 2015 edition moves away from “Watershed Management Area (WMA)” concept from 2001. This approach was tested and found to not greatly add value to the solutions identification process.
- The 2015 edition no longer uses the reach naming convention from the 2001 edition; this system is no longer necessary with the use of GIS to better locate problem and solution locations.

2.8 Findings and Recommendations

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- The 2001 Master Plan findings are updated in the 2015 Plan; progress made in the intervening years and the remaining challenges are acknowledged.
- The 2001 Master Plan was the first of its kind. It documented the abundance of problems and the vast need for solutions—as well as resources to implement them. In the 13 intervening years, much progress has been made to address the problems identified in 2001, but unfortunately, much work remains. This work stems from both from problems identified in 2001 and not yet addressed—namely existing infrastructure continues to age and deteriorate, and new areas have been annexed with undersized or non-existent infrastructure—to new damage created by ongoing large storms and other, inevitable natural forces.
- The 2001 edition contained a detailed critique of the level-of-service for operating programs and made recommendations for these programs. The 2015 Plan reports on the progress of these recommendations, which have largely been addressed, but does not attempt a new level-of-service analysis at this time. The 2001 Master Plan also benchmarked a number of programs, while the 2015 Plan does not present benchmarking.
- The 2001 Master Plan presented detailed recommendations on the 30 then existing programs and 6 new programs. The 2015 edition gives an update on the status of all 36 of these entries and recommends additional, targeted program enhancements.
- Much progress has been made in improving and expanding programmatic solutions and consequently, the list of needs is shorter. But the challenge of assets maintenance for our infrastructure remains. In fact, with materials and labor costs for construction increasing, the cost to repair and replace this infrastructure is likely higher than would have been anticipated in 2001.
- Similarly, much progress has been made in updating Austin's regulations. The 2001 edition recommended 16 regulatory improvements. The 2015 Master Plan gives an update on the status of these items, along with 13 additional recommendations offered in the intervening years. Progress included over 220 changes and improvements with Council's passage of the Watershed Protection Ordinance in October 2013. Out of the 29 total regulatory recommendations, all but two have been implemented. Of the two not addressed, one is no longer needed and the other is no longer possible. Important regulatory work remains—e.g., to address needs to beneficially use stormwater for improved hydrology and water conservation—but the list is much shorter.
- Three new regulatory recommendations have also been presented in the 2015 update.

2.9 Watershed Summaries

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- The 2001 Master Plan presents an individual watershed summary for each of the 17 Phase 1 watersheds. A new system is presented in the 2015 Master Plan update using "Watershed Profiles." Individual summary information by individual watershed was judged no longer feasible at this time for the 49 Phase 1 and 2 watersheds now under study. Instead, a new Appendix C was created to present Watershed Profile information for watersheds citywide for eight targeted water quality problem types. Future Master Plan updates will include more specific information on small groups of like watersheds; these summaries will also contain flood and erosion control elements.

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Appendix B

1 Erosion Assessment

This appendix presents additional data collected during the Phase 1 Watershed Erosion Assessments concerning existing and predicted future channel enlargement. This information shows the extent of past erosion and underscores potential areas of future erosion. But this system is no longer used in the current erosion scoring system and thus is included here only as a reference.

1.1 Channel Enlargement Estimates

The Phase 1 Erosion Assessments include a procedure to estimate historic and predicted future channel enlargement as a function of watershed impervious cover. Determining the enlargement potential for each like reach provides an estimate of the expected channel enlargement, corresponding sediment load to the creek and the identification of erosion hazard areas. Channel enlargement occurs primarily through **downcutting** (the channel bottom is progressively washed away) and **widening** (the channel side slopes are progressively washed away). As runoff volumes increase due to urbanization, the channel's resistance to erosion is surpassed and they become larger. The rate at which erosion is accelerated is dependent on the channel type (e.g., alluvial channels tend to erode faster than rock channels).

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Appendix B Table 1.1-1 Phase 1 Watershed Stream Reaches by Stability Class (1997)

Watershed	Number of Stream Reaches		
	Stable	Transition	In Adjustment
Barton	9	1	0
Blunn	0	2	3
Boggy	1	3	3
Bull	2	14	5
Buttermilk	0	4	1
Country Club	1	1	6
East Bouldin	1	3	0
Fort Branch	1	4	5
Harpers Branch	4	2	0
Johnson	6	4	1
Little Walnut	0	15	1
Shoal	3	10	5
Tannehill Branch	2	5	1
Waller	4	6	2
Walnut	6	21	7
West Bouldin	1	2	2
Williamson	4	8	7
Total	45	105	49

Source: Raymond Chan & Associates, May - Oct, 1997.

To predict channel enlargement, “channel enlargement curves” were developed that relate increases in channel size (as a ratio of future size to existing size) to increases in impervious cover for three channel types – alluvial, rock bed, and rock-controlled. An empirical approach was applied based on the development and calibration of channel enlargement curves using observed local creek data. These methods are patterned after similar studies across the United States (Morisawa and Laflure, 1979; Allen and Narramore, 1985; MacRae et al., 1994) that use changes in impervious cover within a watershed as an indicator to reflect changes in stream erosion potential. The mechanics of the approach are described in detail in Technical Procedures for the Watershed Erosion Assessments (RCA, 1997).

A detailed study of 60 sites was used to develop the enlargement curves. Estimates of current and future (year 2040) impervious cover used in this analysis were developed on a watershed basis (CRWR, 1997). Based on a follow-up analysis on the Walnut Creek Watershed (RCA, January 1999), initial estimates of predicted future channel enlargement were modified to reflect the beneficial effect of sedimentation-filtration ponds anticipated to be constructed for new development. The City’s Land Development Code requires structural water quality controls of all new development.

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The runoff volumes detained in these structures help reduce in-stream stormflow volumes, thereby reducing the future enlargement potential.

Estimates of past and predicted future channel enlargement for the Phase 1 watersheds are illustrated in Figure 6.2-4 and Figure 6.2-5, respectively. From Figure 6.2-4, it is clearly evident that the most significant channel enlargements have occurred in the urban watersheds. Many creek reaches in the urban watersheds have more than doubled in channel size

Urban development increases the frequency of bankfull flows over the course of an average year. This effectively increases the erosion potential for the stream system. This phenomenon is reflected in the high number of erosion problems identified in the most heavily urbanized watersheds as shown in Figure 6.2-4.

One of the most significant findings of the 2001 Master Plan is shown in Figure 1.1-2. Based on predicted development levels and resulting increases in impervious cover, substantial increases in channel area are predicted for many of the suburban watersheds. The predicted channel enlargements take into account the benefits expected from sedimentation-filtration basins constructed for new development as discussed earlier for only the Nonurban watersheds (Barton, Bull, Country Club, Walnut and Williamson Creek watersheds). These benefits were not applied to the Urban watersheds due to the fact that the majority of the Urban watersheds are already developed.

In many cases, high levels of predicted channel enlargement are found in areas where:

1) creeks and tributary channels are composed of alluvial materials, and
2) their contributing watershed areas are expected to experience substantial increases urban development.

It should be noted though that future predicted increases in channel area are not solely a response to future development in the watershed. Erosion occurs over a period of many years (over 50 years for example). Much of the predicted future channel erosion is a delayed response to increases in stormflows from existing development.

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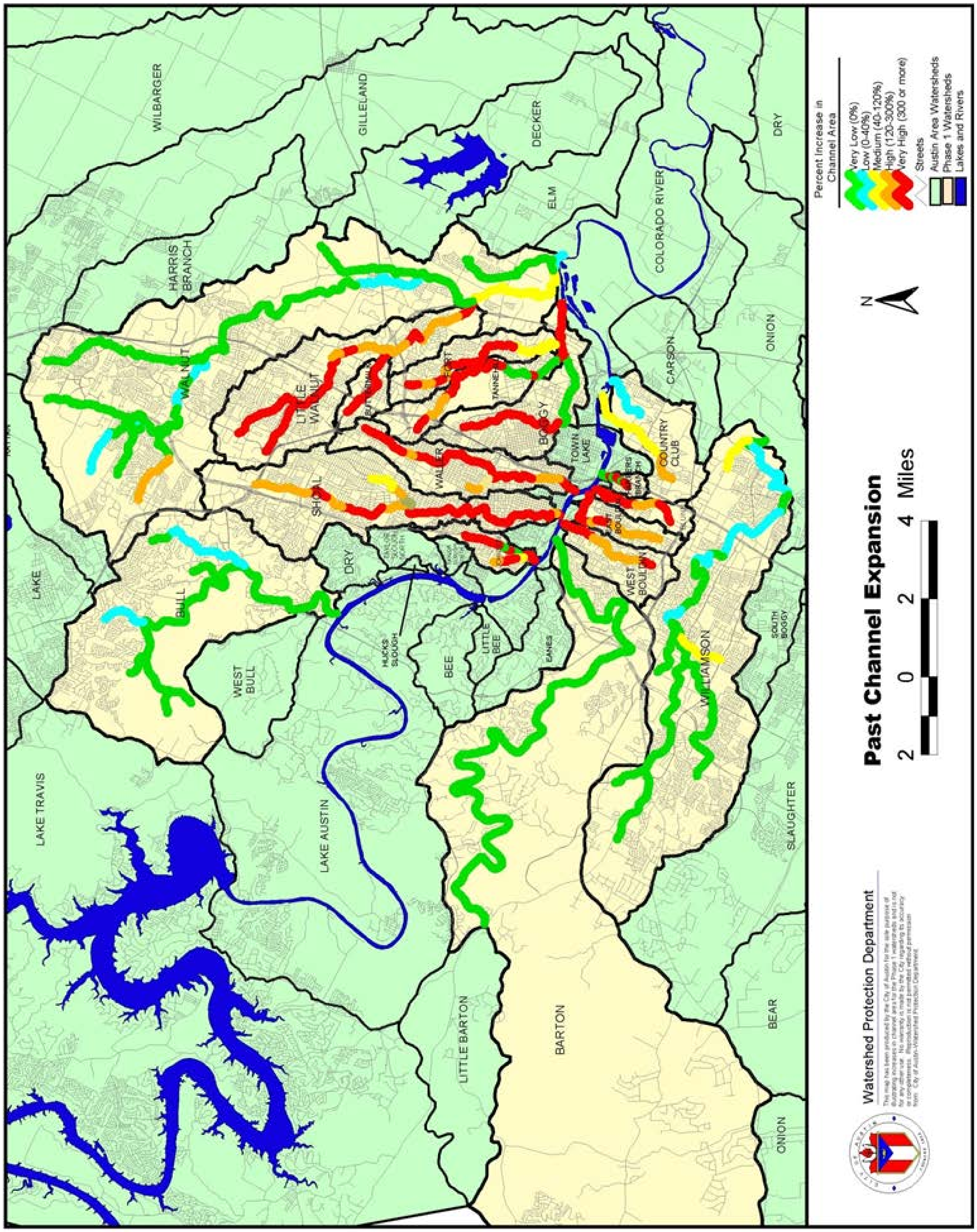

Appendix B Figure 1.1-1 Past Channel Expansion

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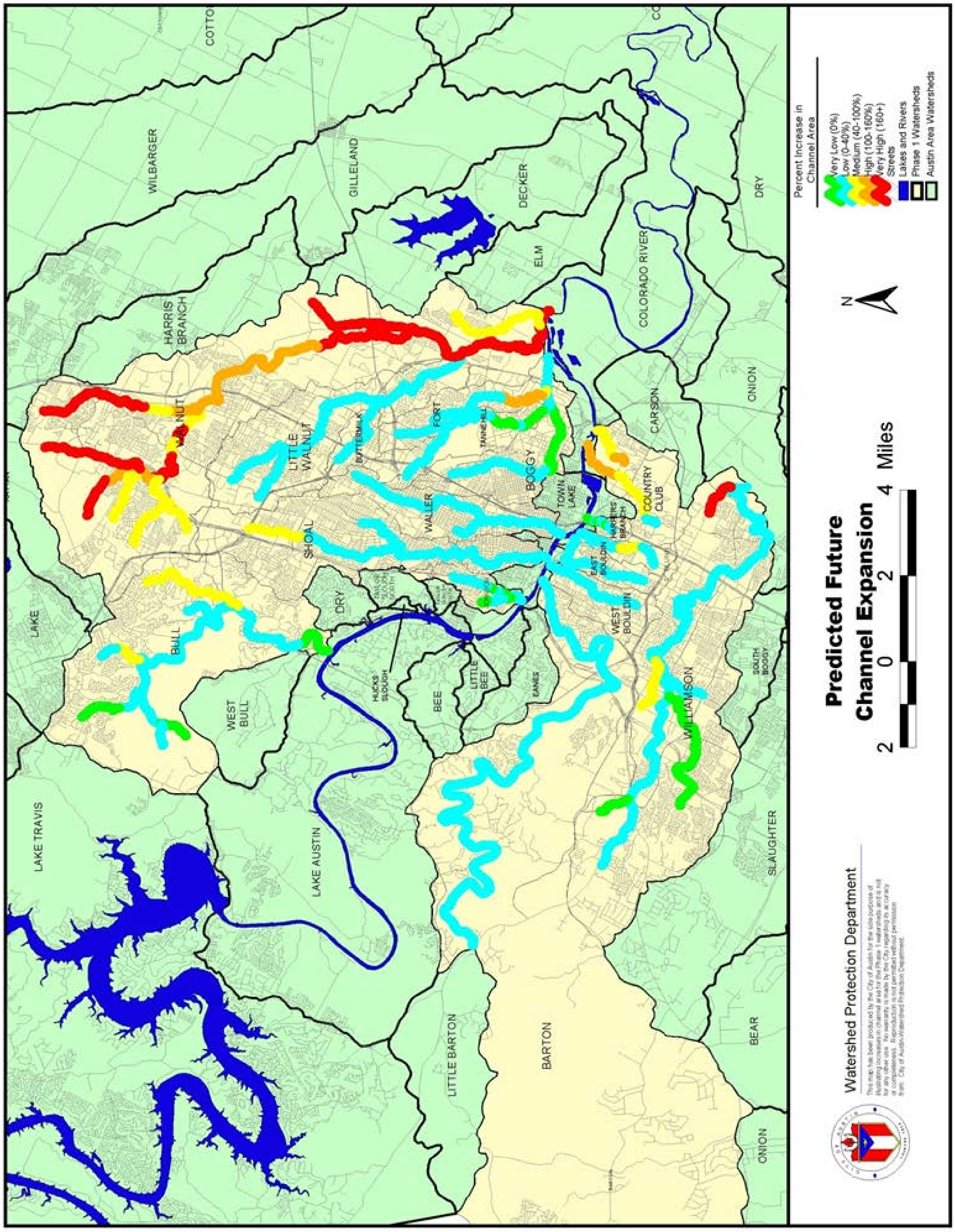

Appendix B Figure 1.1-2 Predicted Future Channel Expansion

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Appendix C

Watershed Profiles

1 Introduction

This Appendix presents eight Watershed Profiles that focus on citywide solutions to address water quality problems. This system replaces the original 2001 Master Plan system of individual watershed summaries for the Phase 1 watersheds. The water quality mission was selected as the first to consider with the Watershed Profiles given its historic complexity (e.g., 27 different factors monitored by the EII alone) and the relative difficulty in implementing feasible solutions in comparison to the other missions. See below for a discussion of future additions planned for the Watershed Profile system.

1.1 Watershed Profile Contents

Eight Watershed Profiles are presented below. Each focuses on citywide solutions used to address one of eight specific water quality problems. Each problem score is derived from Environmental Integrity Index (EII) subcomponents. In addition to the Watershed Profile summaries, a Base Map was developed for each water quality problem score. The Base Map is an ArcGIS (digital mapping analysis) document that organizes and displays data related to the problem score, including both potential sources and solutions. The purpose of the Base Map is not only to provide a clearinghouse of related data, but also to allow spatial correlations of potential sources and solutions with the problem scores for individual EII reaches.

Each Watershed Profile below contains the following structure:

- **Problem Score Calculation**. Brief discussion of how the problem score is calculated as well as a description of the potential impacts of the pollutant on surface and groundwater resources.
- **Base Map Overview**. Summary of the Base Map compiled for the problem score, including examples of data, and a map of the problem score by EII reach.
- **Actions**. Summary of actions by the City of Austin and other partner organizations (e.g., Keep Austin Beautiful) to solve the identified problem. Includes an introduction discussing the three-tiered approach of programs, regulations, and capital improvement projects, giving examples for each.
- **Case Studies**. Description of Austin-area projects or research involving identification and mitigation of problems.
- **Supporting Documentation**. Selected literature produced by the City of Austin or central to City of Austin solutions.

1.2 Future Watershed Profiles

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In a future Master Plan update, the Watershed Profiles will be expanded to provide the following information for each watershed category for all missions (Flood Mitigation, Erosion Control, and Water Quality Protection):

- Summary of existing data and analysis, including natural features and infrastructure;
- Catalogue of existing problems, including problem scores and priorities for each mission;
- Catalogue of historic and ongoing solutions, including projects, regulations, and programs; and
- Identification of potential future solutions.

Information collected for the Watershed Profiles will be tailored to small groups of related watersheds instead of the current citywide format. Each of these watershed groupings will be selected to address their unique challenges (e.g., existing urbanization versus greenfield development) and potentially require different sets of solutions (e.g., prevention vs. restoration). A selection of the available information will be displayed on an interactive online platform to enhance the usability and accessibility of the data. Once completed, the Watershed Profiles will continue to be refined and updated over time as new data becomes available.

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2 Bacteria from Animals

2.1 Problem Score Calculation

Bacteria from animals = min(nutrient or % algae EII) - (bacteria EII)

This score prioritizes stream reaches with high indicator fecal bacteria but without correspondingly high levels of nutrients or algae growth suggesting that fecal contamination is from animals and not leaking wastewater infrastructure. Companion animals are a significant nonpoint source of fecal contamination in urban areas. In some highly urban areas, human transients are also a source of fecal contamination (e.g., Waller Creek). Confined animal feeding operations or wildlife may be sources in less developed areas. Birds may also be a source, particularly over some elevated roadway creek crossings and marshy areas with long hydroperiods.

Austin's waterways have long been impacted by bacteria linked to animals. Bacteria from animals can pose a significant health risk to people and pets, especially children who encounter it while playing. Animal waste contains dangerous bacteria, like salmonella and E. coli, and harmful parasites, like giardia and roundworms. These hazardous organisms persist in the waste for days or months after deposit. It takes only one teaspoon of dog feces in a water body the size of an Olympic pool to make water unsafe for swimming. Animal waste washed into our lakes and creeks can also cause aquatic weeds and algae to flourish, eventually causing reduced levels of oxygen in the water that result in fish kills.

Bacteria data is assessed by TCEQ to determine contact recreation use support and identify impaired water bodies on the 303(d) list, and impairment designation does not differentiate between animal or wastewater sources. Impairments must be addressed by a Total Maximum Daily Load (TMDL) to determine the source of the impairment, and corrected by an Implementation Plan. See Gilleland Creek TMDL and Implementation Plan below for an example. Not all Watershed Protection Department monitoring data is submitted to TCEQ and assessed in the 303(d) process. WPD submits monitoring data to TCEQ for assessment through the Texas Clean Rivers Program at selected sites in Lady Bird Lake, Lake Long, Barton Creek, Bull Creek, Walnut Creek, and Onion Creek. In addition, the Austin/Travis County Health and Human Services Department monitors bacteria levels at Barton Springs, Bull Creek, and McKinney Falls State Park.

2.2 Base Map

The Base Map is an ArcGIS document that organizes and displays data related to bacteria from animals, including both potential sources (e.g., off-leash areas, bridges) and potential solutions (e.g., mutt-mitt stations, stormwater controls). The purpose of the Base Map is not only to provide a clearinghouse of related data, but also to allow staff to spatially correlate potential sources and solutions with the problem scores for individual EII reaches.

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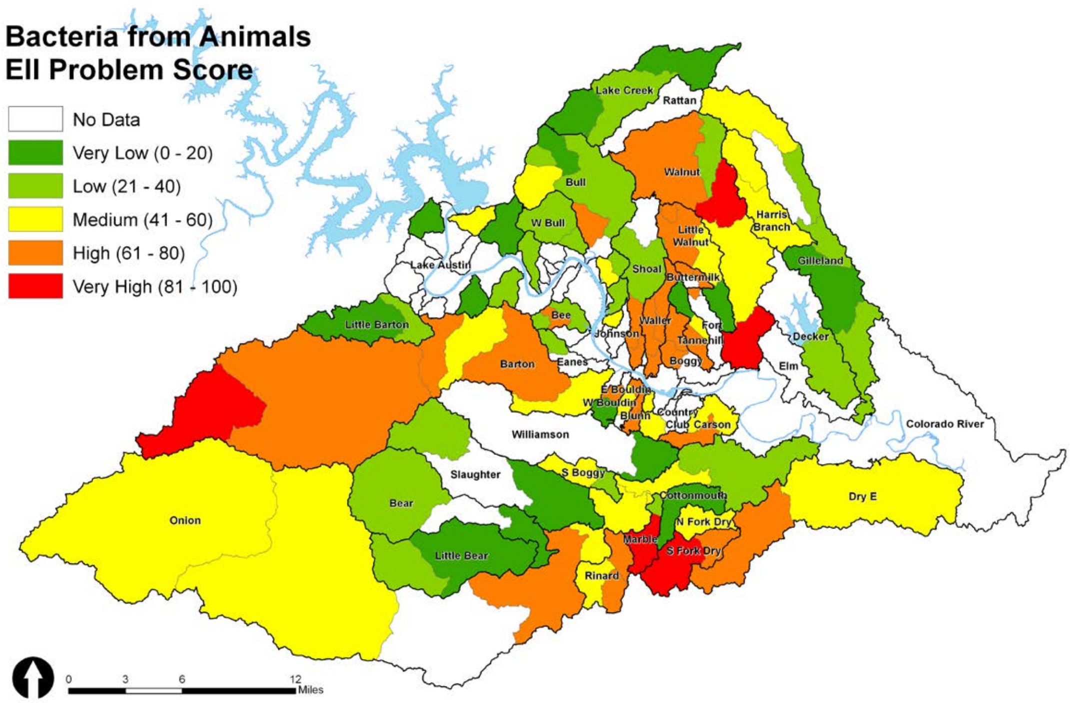
This data was identified through meetings with internal department stakeholders and is a combination of existing GIS data as well as newly-created GIS data. Upon completion, the Base Map was reviewed by the internal stakeholders and additional updates were completed.



2.3 Actions

Introduction

The Watershed Protection Department addresses water quality degradation associated with bacteria from animals using a three-tiered approach of programs, regulations, and capital improvement projects.

Examples of programmatic solutions include public education (see Scoop the Poop!), research (see Bacteria Source Identification, Birds and Bridges Study), and monitoring (see Gilleland TMDL, Bull Creek Off-Leash Area).

Examples of regulatory solutions include requirements for development to provide riparian buffers (known as Critical Water Quality Zones) as well as water quality controls. For more information on the benefits of these tools for removing bacteria, see Riparian Zone Restoration and Stormwater Best Management Practices.

Examples of capital improvement projects include a riparian restoration project at Willowbrook Reach in Boggy Creek (see Riparian Zone Restoration), the construction of multiple water quality controls (see Stormwater Best Management Practices), and a riparian restoration and rain garden construction project at Bull Creek District Park (see Bull Creek Off-Leash Area).

As evidenced by the overlap above, problems are often tackled using a combination of all three approaches. The Implementation Plan for the Gilleland Creek TMDL prescribed an array of programs (e.g., outreach efforts), regulations (e.g., headwaters protection), and capital improvement projects (e.g., an extended detention retrofit pilot).

Pet Waste Education - Scoop the Poop!

Pet waste not properly disposed of in public places and in backyards poses a direct contact health hazard to people and pets. As it enters into our local waterways, carried by rain or water from irrigation systems, the waste has a deleterious effect on public health and freshwater ecosystems. Sixty thousand pounds of pet waste—the equivalent of five dump truck loads—is deposited by Austin's dog population every day, making the cumulative effect enormous, and totals approximately 22 million pounds of dog waste per year.

Since 1992, the City has relied on an ordinance requiring that pet owners pick up after their pets to help curb the problem of pet waste. The code is a helpful deterrent but is hard to enforce because it requires a law officer to witness the offense, and it does nothing to increase public awareness of the environmental and health impacts associated with pet waste. Since legal consequence on its own could not address the problem, the City's Watershed Protection and Parks and Recreation Departments initiated the Scoop the Poop program in 2000 to educate pet owners and to facilitate waste cleanup. In the summer of 2009, the program was revamped with a friendly outreach message and mascot, and through the use of broadcast media, social media, public events, and outreach in numerous other avenues, the Scoop the Poop message has been expanded citywide. New components of the program, such as a Facebook page, residential yard signs, and an article for neighborhood newsletters, allows the public to take an active role in promoting the message, which has exponentially increased our reach.

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These educational efforts have also proven a measurable success. In 2008, prior to a targeted outreach campaign, dog owners were surveyed at an off leash dog park with excessively high bacteria in the adjacent creek. The post campaign survey results revealed a significant increase in responsible pet owner behavior - 96% of pet owners picked up their dog's waste always/most of the time after the outreach campaign, compared to 87% in the pre-program survey. With an estimated 0.5 pounds of waste collected per bag, the program's bag distribution in parks prevented more than 1 million pounds of pet waste from entering our waterways this past year.

The program is a joint effort, involving cooperation from several City departments and supportive organizations:

- WPD manages the program, provides the funding and materials, and generates public outreach opportunities.
- PARD installs the dispensers and signs, restocks the bags, distributes information at off-leash dog parks, responds to citizen complaints, and enforces city code through Park/APD police. PARD Rangers distribute information on occasion in the parks.
- Austin Animal Shelter distributes information on-site and at public events and helps fund giveaways.
- Health and Human Services Department distributes information, coordinates volunteer cleanup events, and enforces City code through animal control officers.
- Austin Parks Foundation distributes information at off-leash dog parks.
- Keep Austin Beautiful coordinates volunteer pet waste cleanup events.
- The Off-Leash Area Advisory Committee (OLAAC) hosts park clean-ups and is raising money for educational kiosks (Scoop the Poop program has given money to help fund the kiosks).
- Four non-profit organizations (Austin Humane Society, Animal Trustees of Austin, Austin Pets Alive, and Emancipet) are partnering with the Scoop the Poop program and helping get the word out via their social media networks, newsletters, and websites; event tablecloths; banners; posters; giveaway items, etc.

Information and resources are available to citizens year-round on the Scoop the Poop website: Scoopthepoopaustin.org.

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Bacteria Source Identification

WPD monitoring for the Environmental Integrity Index has identified a large number of fecal impaired watersheds in Austin. There are currently 50 sites not supporting contact recreation based on indicator bacteria measurements versus State standards, and WPD staff have identified more than 15 as having significant contact recreation potential. There are 47 EII reaches that have contact recreation scores less than “Fair”. It is a goal of the Watershed Protection Master Plan to improve both water quality and contact recreation subindex scores in these watersheds.

WPD monitoring for the Clean Rivers Program (CRP) has identified 5 watersheds that are federally impaired for bacteria, which are on the 303(d) list for impaired contact recreation: Upper Walnut, Taylor Slough South, Gilleland, Spicewood Tributary to Shoal Creek, and Waller Creek .The City of Austin is currently developing a TMDL with the TCEQ for four of these watersheds: Walnut, Taylor Slough, Spicewood Tributary to Shoal Creek, and Waller Creek. For more information of this TMDL, see the Sewage Watershed Profile. A TMDL is already in effect for Gilleland Creek. Additionally, there are potential fecal contamination issues related to off-leash dog use in Bull Creek at Bull Creek District Park (see Bull Creek case study) and Barton Creek below Barton Springs. The bacteria source identification project is designed to identify the source of the fecal contamination to more efficiently direct remediation with the goal of removing the impairments, continuing routine indicator bacteria monitoring under uncontaminated circumstances through CRP.

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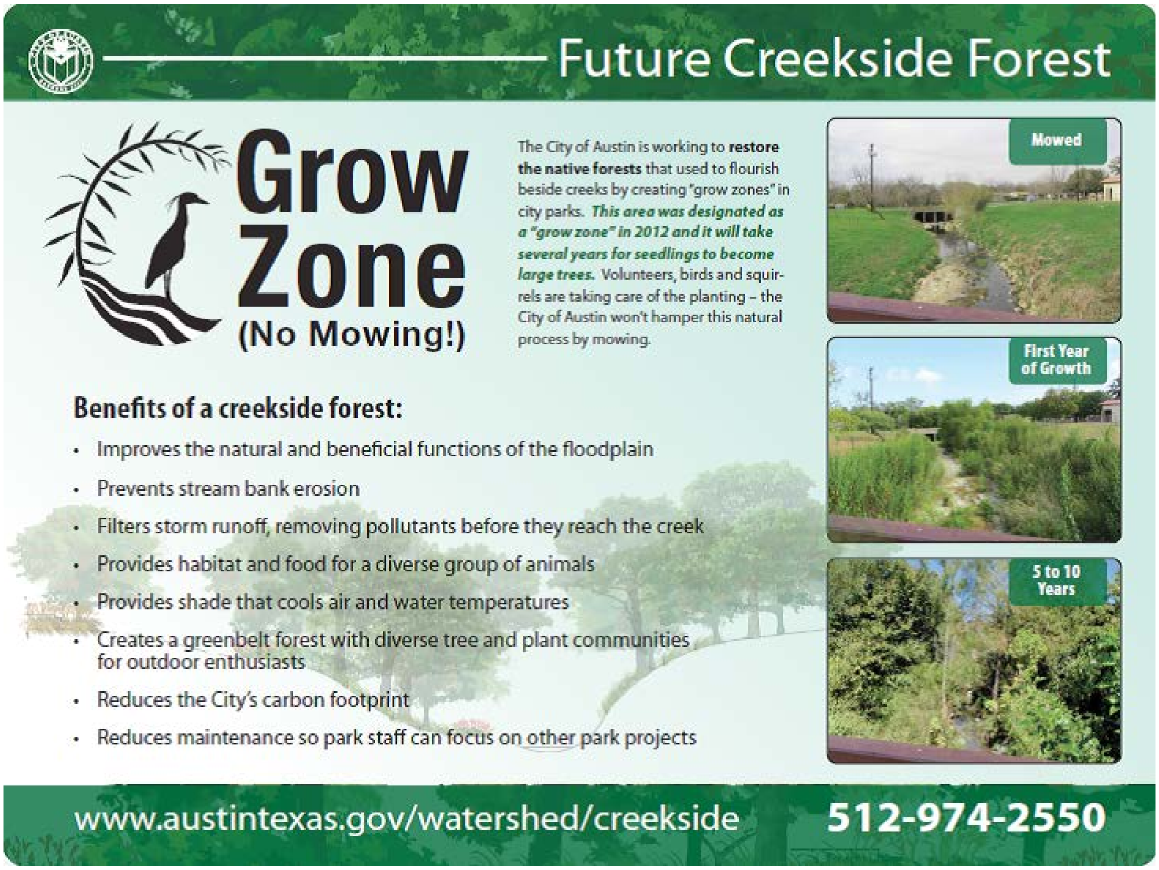
This project will evaluate the cost-benefit ratio and effectiveness of advanced bacteria source tracking methods, including both genetic and chemical source tracking methods. Microbial methods include both library-dependent enterobacteria repetitive intergenic consensus polymerase chain reaction (ERIC/PCR) and riboprinting combination (ERIC-RP), and library-independent quantitative PCR for Bacteriodales markers. Evaluation of the applicability of the Texas Known Source Library to local samples will be assessed. Chemical methods include isotopic analysis (both strontium and oxygen isotopes of nitrate) and sampling for chemical wastewater indicators (e.g., caffeine). Expansion and evaluation of the effectiveness of public education will also be included.

Implementation of solutions will include coordination with Austin Water when source tracking identifies leaking wastewater infrastructure as the source of fecal contamination, or conversely identifies that fecal contamination is from other sources so that additional AW investigation is unnecessary. AW has participated in previous joint bacteria studies with WPD (Bull Creek).

Riparian Zone Restoration

The Riparian Zone Restoration (RZR) program of the City of Austin is focused on improving riparian zone function in all of Austin's stream systems by improving the vegetative communities in these buffers, improving soil health and infiltration capacity, and increasing the ability of storm flow to be slowly and evenly distributed through riparian areas. Pathogenic bacteria in streams is a significant water quality problem, primarily as it restricts contact recreation, but it also serves as an indicator or surrogate for other pollutants that are associated with it such as nutrients and low dissolved oxygen. Healthy riparian buffers enhance water quality and quantity in a wide variety of ways, including reducing nutrients and suspended solids. Riparian buffers will reduce bacteria loads to streams from stormwater, primarily due to the fact that bacteria tend to adhere to sediment particles that are the most easily filtered out pollutant in stormwater. By targeting stream reaches with non-existent or degraded riparian areas, and ensuring that vegetation and then soil health are improved, and that storm flow is routed through these restored buffers, overall bacteria loads to these streams should be reduced significantly over the long term. See the Poor Riparian Vegetation Watershed Profile for more information on the planning, design, and implementation of Riparian Zone Restoration projects.



Stormwater Best Management Practices (BMPs)

BMP designs that maximize exposure to sunlight, provide habitat enabling predation by other microbes, provide surfaces for sorption, provide filtration, and/or allow sedimentation should reduce bacteria concentrations. Practices that infiltrate stormwater will reduce bacteria loading (flow x concentration) by reducing the volume component of the load. Practices that infiltrate stormwater also typically provide treatment processes enabling sorption and filtration. Where infiltration is used, it is important to recognize that groundwater pollution can also occur, if adequate sorption and filtration do not occur prior to the infiltrated flows reaching groundwater.

Currently available data suggest that it is unlikely that conventional structural BMPs can consistently reduce bacteria concentrations in runoff to primary contact recreation standards. In terms of reducing overall bacteria loads to receiving waters, site designs and individual BMPs that reduce runoff volumes should reduce bacteria loading from urban runoff. However, this does not necessarily mean that the receiving waters will attain stream standards if runoff is retained onsite.

At the BMP category level, retention (wet) ponds, and various types of media filters may help to reduce bacteria concentrations, although not necessarily to stream standards. Unit processes such as sorption and filtration are present in bioretention and media filters, whereas wet ponds may provide long holding times that enable sedimentation, solar irradiation, and habitat conducive to natural predation. Individual bioretention studies also appear to reduce bacteria concentrations, but more studies are needed for this category of BMPs to draw category-level conclusions. Based on the unit treatment processes provided in retention ponds, media filters, and bioretention, bacteria reductions are expected, so the data, for the most part, support the theory.

In general, grass swales/strips and detention basins do not appear to provide meaningful reduction in bacteria concentrations and often show net export of indicator bacteria. These BMP types may require enhancements to improve specific additional treatment processes such as filtration and sedimentation. However, it should be noted that volume reductions may be significant, so these BMPs may be effective at reducing bacteria loadings to receiving waters.

Gilleland Creek TMDL and Implementation Plan

Gilleland Creek was placed on the State of Texas' 2004 303(d) list because one or more of its stream segments exceeded the standard for bacteria in waters designated for contact recreation use. Listed water bodies require remedial action by the state to restore water quality. TCEQ may choose to develop a restoration plan, reevaluate the appropriateness of a water body's standard for that use, or collect more data and information to determine what management steps are needed.

In the case of Gilleland Creek, TCEQ worked with stakeholders to develop a scientific allocation called a total maximum daily load (TMDL) and an implementation plan ("I-Plan"). The Gilleland Creek Implementation Plan, adopted by TCEQ in 2011, includes six management measures and one control action to reduce bacteria. Management measures are voluntary activities and included the following:

- Identify, prioritize, inspect, and bring into compliance malfunctioning OSSFs in the Gilleland Creek watershed.
- Restore and preserve riparian zones to protect water quality.

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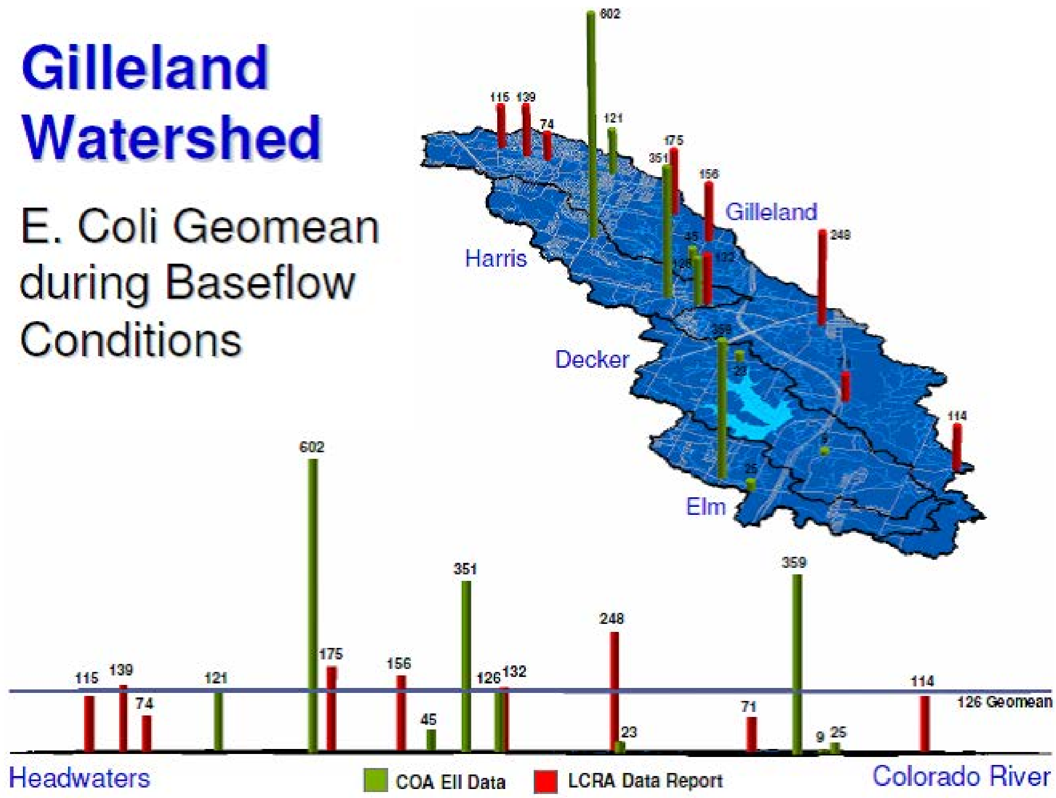
- Determine the effectiveness of retrofitting existing stormwater detention basins to perform as water quality facilities to reduce bacteria concentrations.
- Partners coordinate to develop a general campaign to raise public awareness of unregulated contributions of bacteria pollution, specifically pet waste.
- Develop and adopt equivalent water quality ordinances between government jurisdictions.
- Conduct annual visual inspection of wastewater collection systems within 100 feet from the centerline of Gilleland Creek and its tributaries.

Control actions are regulatory activities – in this case, monitoring and reporting E. coli concentrations from WWTF effluent (http://www.tceq.texas.gov/waterquality/tmdl/69-gillelandcreekbacteria.html)



2.4 Case Studies

Bull Creek Off-Leash Area

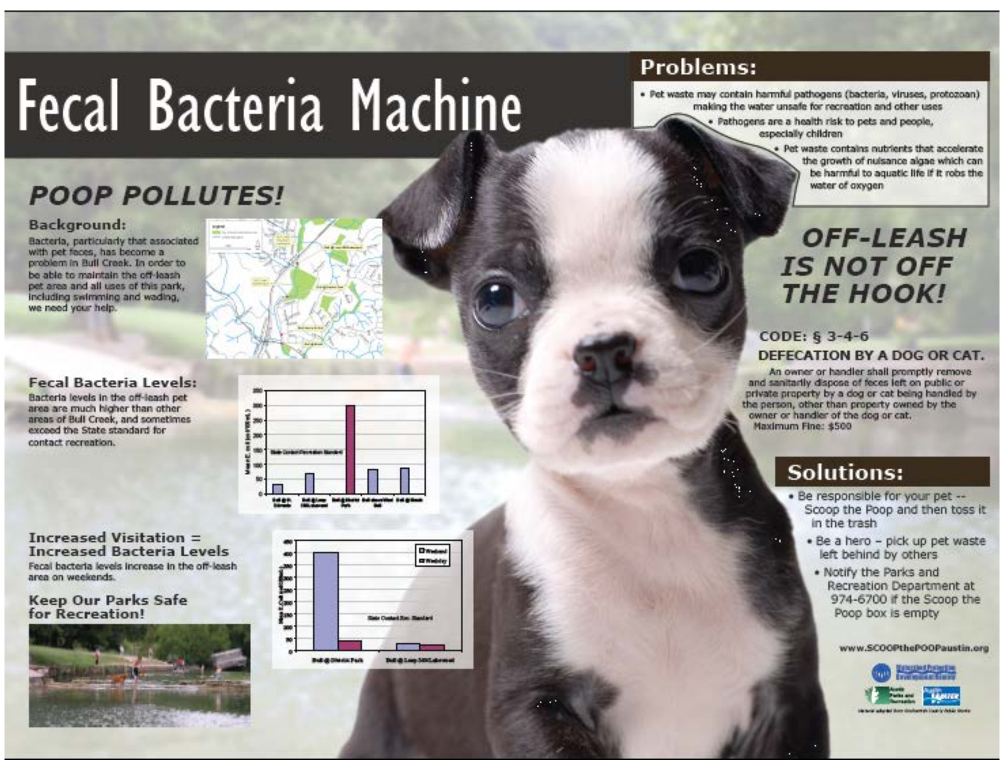
Lower Bull Creek District Park, near the intersection of Lakewood Drive and RM 2222 in northwest Austin, frequently exhibits indicator bacteria concentrations that exceed State of Texas water quality standards for contact recreation. The impairment is localized in the lower portion of the park.

A joint task force consisting of representatives from the Watershed Protection Department, Austin/Travis County Health and Human Services Department, the Austin Water, and the Parks and Recreation Department was formed to identify the source of the water quality impairment and recommend potential solutions that would reduce the further degradation of the water body and risk to human health.

The task force identified that the most likely source of the impairment is recreational use of the park; specifically, off-leash dogs within the park that are entering the water, functioning as a vector for dog excrement in the park and/or agitating potentially contaminated bottom sediments.

2008 Report: http://www.ci.austin.tx.us/watershed/publications/files/SR-08-02%20Bull_Contact_Rec.pdf

2011 Update: http://assets.austintexas.gov/watershed/publications/files/SR-11-07%20Bull%20Creek%20Bacteria%20Update%202010.pdf



Case Study: Birds and Bridges Study

The University of Texas Center for Transportation Research performed a study in 2010 that investigated whether cliff swallows nesting on the undersides of bridges increased the loading of fecal indicator bacteria (FIB) to the underlying creek. Two bridges were monitored, one on Bull Creek and one on the Guadalupe River in Kerrville, Texas. The results of the study at Bull Creek suggest that nesting colonies of cliff swallows on bridges are a significant source of E. coli and fecal coliform during the nesting period. The concentrations downstream of the bridge were significantly higher than the concentrations upstream of the bridge during dry weather.

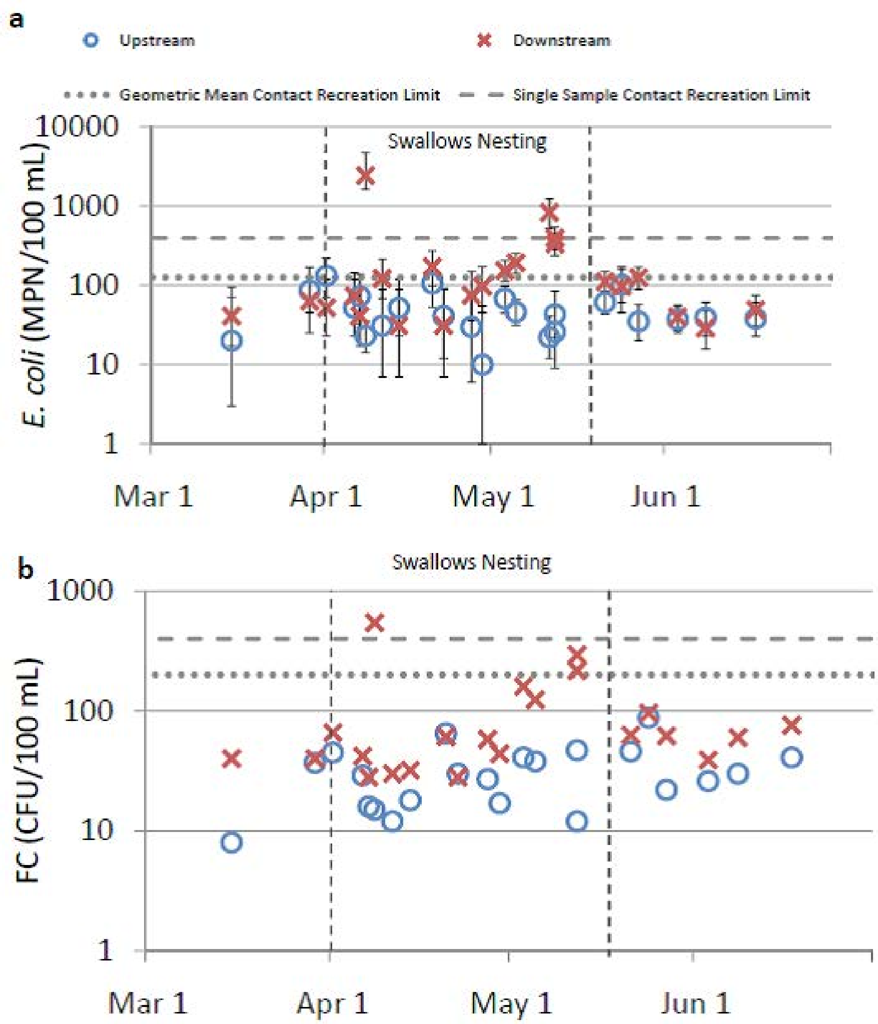


Figure 17: Combined 2009 and 2010 dry weather concentrations of (a) *E. coli* and (b) FC in Bull Creek upstream and downstream of the Loop 360 Bridge when swallows were present. Time when swallows were nesting is noted. All other data correspond with foraging behavior. Error bars represent 95% confidence intervals.

2.5 Supporting Documentation

Texas Surface Water Quality Standards, which establish the type and criteria for indicator bacteria to support designated or assumed contact recreation uses of water bodies: http://info.sos.state.tx.us/pls/pub/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=307&rl=Y

TCEQ Implementation Manual, describing procedures by which bacteria data should be assessed: http://www.tceq.texas.gov/assets/public/compliance/monops/water/10twqi/2010_guidance.pdf

TCEQ 303(d) list: http://www.tceq.texas.gov/waterquality/assessment

TCEQ Recreational Use-Attainability Analyses (RUAAs) Procedures: http://www.tceq.state.tx.us/assets/public/waterquality/standards/ruaa/Recreational%20UAA%20Procedures_Final_2012.pdf

On-going EPA research activities: http://water.epa.gov/scitech/swguidance/standards/criteria/health/recreation/index.cfm

Contact recreation guidelines in Town Lake: http://www.cityofaustin.org/watershed/downloads/townlake_rec.pdf

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Young, R. A., Huntrods, T., and Anderson, W. 1980. Effectiveness of Vegetated Buffer Strips in Controlling Pollution from Feedlot Runoff. J. Environ. Qual., Vol. 9, no. 3

http://www.bmpdatabase.org/Docs/BMP%20Database%20Bacteria%20Paper%20Dec%202010.pdf

http://www.bmpdatabase.org/Docs/2012%20Water%20Quality%20Analysis%20Addendum/BMP%20Database%20Categorical_SummaryAddendumReport_Final.pdf

http://water.rutgers.edu/Research/buffer_pollutant_removal_lit_review_03292010.pdf

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3 Construction Runoff

3.1 Problem Score Calculation

Construction Runoff = (bank stability EII) – average (Total Suspended Solids, sediment deposition EII)

This score prioritizes stream reaches with stable banks but high in-stream suspended solid concentrations during baseflow conditions from water quality sampling and high sediment deposition from visual assessment potentially from uncontrolled sediment runoff from development activities. Bank stability is included in the calculation to exclude highly depositional reaches where the source of stream sediments is likely bank sediments from erosion of unstable areas.

The conversion of land from its natural state or agricultural use to urban use accelerates the processes of erosion and sedimentation. These negatively impact the city's drinking water supply, aquatic life, and recreational resources. Construction-related sediment can be a significant pollutant of streams, lakes, ponds, and reservoirs. Not only does sediment reduce the quality of water for boating, fishing, swimming, and other water-oriented recreation, it also creates maintenance problems due to excessive wear on pumps and due to the reduced capacity of streams, lakes, and other waterways. Fine sediment (clay and dirt) runs off of disturbed or erosive areas and construction sites and is carried to creeks by stormwater. Suspended sediment can block light needed by aquatic plants and algae and when it settles out on stream bottoms, smothers stream organisms and eliminates critical habitat. It is one of the most pervasive and damaging pollutants in stream systems because its effects are immediate and it is difficult to remove. Another problem associated with sediment is the affinity of pesticides, phosphates, and many other chemical pollutants for soil particles. These pollutants are carried to the waterway on the sediment and further reduce the quality of the water.

Development accelerates the erosion process by modifying the topography, soil conditions, vegetative cover, and drainage patterns during construction. The clearing and grading of land to convert it from a natural state to cultivated row crops greatly increases the potential for erosion. The magnitude of this increase can be as much as 200 times. In addition, earth moving and construction to convert agricultural land to urban uses such as roads, houses, shopping centers, schools and airports increases the erosion potential another 10 times. On most development projects, the major period for erosion potential exists between the time when the existing vegetation is removed to begin site work and the completion of construction and revegetation. After full urbanization takes place in a watershed, however, erosion usually decreases several-fold from that experienced during the period of construction and may even decrease from that occurring before construction.

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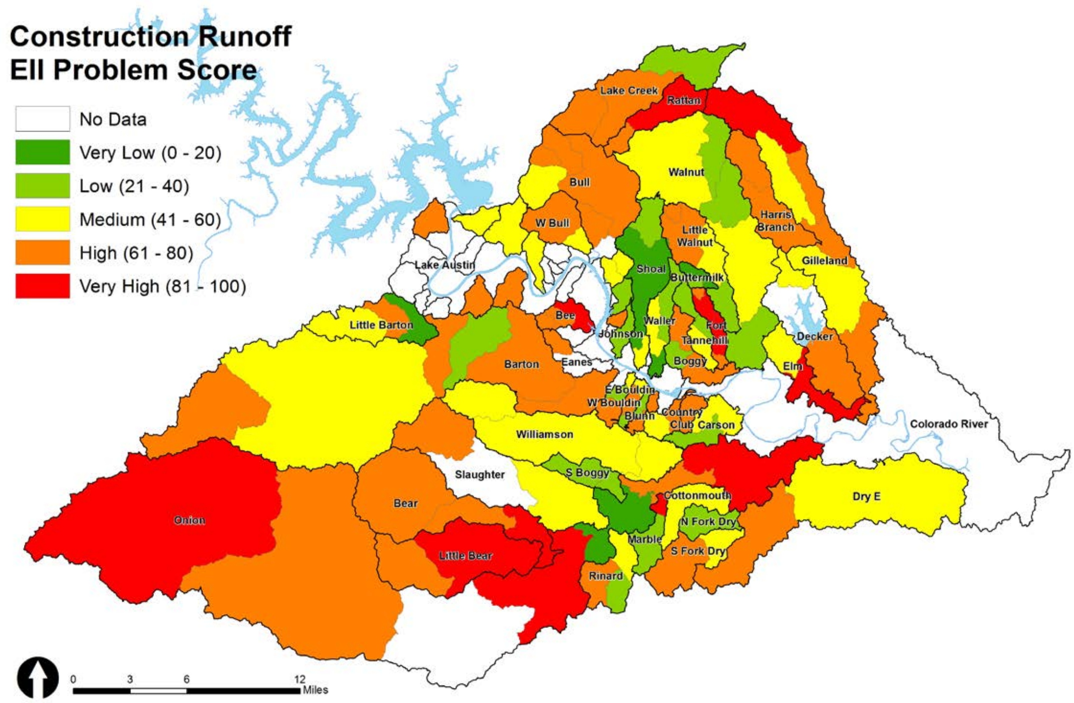
3.2 Base Map

The Base Map is an ArcGIS document that organizes and displays data related to construction runoff, including both potential sources (e.g., site plans) and potential solutions (e.g., inspector areas). The purpose of the Base Map is not only to provide a clearinghouse of related data, but also to allow staff to spatially correlate potential sources and solutions with the problem scores for individual EII reaches.

This data was identified through meetings with internal department stakeholders and is a combination of existing GIS data as well as newly-created GIS data. Upon completion, the Base Map was reviewed by the internal stakeholders and additional updates were completed.



3.3 Actions

Introduction

The Watershed Protection Department addresses water quality degradation associated with construction runoff using a three-tiered approach of programs, regulations, and capital improvement projects.

Examples of programmatic solutions include inspection of construction sites (see Environmental Inspection). Examples of regulatory solutions include requirements for erosion and sedimentation controls. Examples of capital improvement projects include the remediation of sites contaminated by construction runoff (see Hamilton Pool Cleanup Case Study).

Erosion and Sedimentation Controls

Erosion and sedimentation controls are required for all construction and development conducted with or without a permit, including without limitation commercial, multi-family, single-family, and duplex construction, the construction of all roads, utilities, parks, golf courses, water quality basins, detention basins, and all other activities utilizing clearing, trenching, grading, or other construction techniques. It is the intent of City of Austin policy to closely parallel the requirements set forth in the Texas Pollution Discharge Elimination System (TPDES) Construction General Permit, the City of Austin's MS4 permit and any applicable updates to NPDES or TPDES.

The objectives of the policy are to:

- Minimize the erosion and transport of soil resulting from development activities.
- Prevent sedimentation in streams, creeks, lakes, waterways, storm drains, etc. by ensuring no off-site transport of disturbed sediment for the 2-year 24-hour storm during construction and through establishment of permanent controls.
- Protect and improve the quality of surface water in the Austin environment and maintain and improve the quality and quantity of recharge to groundwater supplies, especially the Edwards Aquifer.
- Minimize flooding hazards and silt removal cost associated with excessive sediment accumulation in storm drains and waterways.
- Preserve and protect existing vegetation to the greatest extent possible, particularly native plant and wildlife habitats.

The Environmental Criteria Manual outlines minimum requirements for the planning, design, construction, operation, and maintenance of erosion and sedimentation control facilities. These criteria were overhauled in 2008 to reflect current science and best practices. The goal of erosion and sedimentation control is to limit as much as possible the detachment and transport of sediment from construction sites and the finished projects they eventually become. Sediment is transported off-site through stormwater runoff, water discharges (e.g.,

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pumping of water out of trenches, open channels, or foundation and basement excavations), vehicles, and wind.

Stormwater runoff and water discharges are the primary means by which sediment is transported from construction sites. Sediment becomes suspended in runoff as it flows over or out of disturbed areas seeking the lowest path of least resistance. The principal tasks are to keep the sediment from entering the runoff or, once in it, to separate and trap the suspended sediment before it can leave the site. The techniques to accomplish this consist of two basic types: site management practices and structural controls.

Site management practices focus on the prevention of erosion and include methods such as minimizing the area of the site that is disturbed at any one time during construction, preserving the existing natural vegetation to the greatest extent feasible, covering exposed soils with temporary stabilization soon after disturbance and restoring vegetation as rapidly as possible in disturbed areas. A related method would be to revegetate between phases of a project, when there will be a delay between these phases. Additional site management techniques include keeping the velocity of stormwater below the erosive level, promoting sheet flow rather than concentrated flow, and protecting and maintaining stable slopes.

Structural controls utilize engineered devices (such as channels, berms, silt fences, ponds, etc.) to keep sediment on-site. This is accomplished in a two-stage process consisting of drainage control followed by sediment removal. The control of on-site drainage is essential to the process, as this

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must be accomplished first in order to successfully separate and trap suspended sediment. Drainage control is accomplished by strategically placing structural controls at locations where they will intercept stormwater runoff as it flows towards the lower portions of a site. These control devices must be substantial enough to withstand the anticipated runoff velocity and either must direct the flow to another control device or must be shaped to temporarily pool the runoff behind the structure. At this point in the process, trapping of sediment can occur. If the drainage control stage is unsuccessful or only partially successful, it will correspondingly limit the amount of sediment that will be trapped.

Environmental Inspection

The Environmental Inspection Section of the Development Services Department (DSD) is responsible for ensuring field enforcement of City water quality regulations, as found in the specific conditions of approved development permits. DSD Environmental Inspectors take the lead role for environmental field inspection of all projects issued site development permits. DSD Site Subdivision Inspectors take the lead role on subdivision construction plans. The Construction Inspection Section of the PWD has the lead authority for inspection of CIP projects, including applicable erosion and sedimentation control (ESC) inspections. DSD Site Subdivision Inspectors monitor compliance with approved ESC plans on subdivision construction plans and PWD Construction Inspectors monitor ESCs on CIP projects and take appropriate enforcement action, as deemed necessary.

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DSD Environmental Inspectors provide assistance on monitoring and enforcement actions relating to ESCs. Proper construction of subdivision on-site drainage facilities and water quality controls is monitored by DSD Site Subdivision Inspectors during the construction process. The purpose of this program is to inspect development projects to ensure compliance with water quality requirements of valid development permits and approved erosion and sedimentation control (ESC) plans; and to ensure proper construction of on-site drainage facilities and water quality controls during the construction process.

At the commencement of development or construction activity, the project site engineer/manager is required to contact the supervisor of the DSD Environmental Inspection, DSD Construction Inspection or PWD Construction Inspection Section. A pre-construction meeting is conducted at project inception, followed by regular site inspections. If during site inspections the inspector finds the applicable ESC plans to be inadequate at a given site, minor modifications to the approved ESC plan and construction sequencing plan may be made in the field to upgrade erosion controls without written DSD approval. Major modifications may require a plan correction. At the final inspection, the appropriate inspector confirms the proper completion of runoff and water quality controls, permanent ESC controls, and site restoration as a prerequisite to project acceptance or issuance of a certificate of occupancy.

If a development project is found in non-compliance with conditions of the development permit during a site visit, an inspector may give the project manager a verbal warning with instructions to achieve compliance within 24 to 48 hours. This action is followed by a written warning if remedial action was not taken to resolve the problems. If corrective actions to bring about compliance are not achieved, a cease-and-desist order may be issued, whereby all work at the project site is stopped until compliance is achieved. A “red-tag” is posted at the site, and a written notice of the cease-and-desist order is mailed to the alleged violator with an explanation of the site factors resulting in non-compliance. If a development project is found to be without a valid development permit and in non-compliance with applicable water quality regulations, or a high priority violation exists, a cease-and-desist order may be issued immediately.

This program coordinates with and assists inspectors from other governmental entities in controlling erosion from active construction sites. Such inspection coordination most commonly occurs with Travis County and the TCEQ. Citizens in the Austin area call Environmental Inspection with complaints and requests for inspections on sites that appear to not be in compliance with the site development permit or might not have a site development permit. Environmental Inspection investigates these complaints, or requests for inspection, and documents the investigation and reports the findings to the concerned citizen. In addition, spills response staff from the Watershed Protection Department investigate incidents that occur after hours and on weekends.

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3.4 Case Studies

Hamilton Pool Cleanup[1]

During and after a rain event on May 31, 2007, inadequate and improper erosion controls at a development known as The Ranches at Hamilton Pool resulted in a massive, uncontrolled discharge of sediment to Hamilton Creek upstream of Hamilton Pool. The discharge transformed the clean waters downstream of the construction site into a dense, milky brown flowage. Hamilton Pool, the world famous natural grotto, renowned for the deep clarity of its waters, was rendered a turbid, murky, near opaque pool with its natural bottom buried by several feet of sediment.

Travis County, the State of Texas, Hays County, and several affected landowners joined together in a civil lawsuit against the developers and their contractors seeking penalties and damages. That civil lawsuit resulted in a settlement agreement under which the developers paid $3.5 million to the plaintiffs. The settlement included payment of $2.1 million to Travis County to defray the costs of cleanup of the creek and Hamilton Pool. The county contracted with Espey Consultants, Inc., a local company that had expertise in remediating a similar sediment discharge at nearby Dead Man's Hole. The Hamilton Creek remediation project was broken up into two phases:

- Phase I involved the removal of sediments from the creek bed upstream of Hamilton Pool. Approximately 6,500 cubic yards of material was removed from the creek system.
- Phase II involved the cleanup of Hamilton Pool itself by filtration. Espey Consultants designed a removal and filtration scenario to capture and separate the silt and sediment from the water body and from the bottom of the pool. Approximately 1,000 cubic yards of silt and sediment was removed from the bottom of the pool and the water column.

Photo courtesy of Travis County, KXAN.

[1] Text and information taken from Travis County Commissioners Court Agenda backup (August 9, 2011)

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3.5 Supporting Documentation

Travis County Commissioners Court Agenda backup (August 9, 2011). http://www.co.travis.tx.us/commissioners_court/agendas/2011/08/backup/eagenda_packet_20110809.pdf

Environmental Criteria Manual – 1.4.0 Erosion and Sedimentation Control. http://austintech.amlegal.com/nxt/gateway.dll/Texas/environ/cityofaustintexasenvironmentalcriteriama?f=templates$fn=default.htm$3.0$vid=amlegal:austin_environment$anc=

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4 Nutrients (Non-sewage)

4.1 Problem Score Calculation

Nutrients (non-sewage) = (bacteria EII) – min (nutrient or % algae EII)

This score prioritizes reaches with elevated nutrients or excessive algae growth without high fecal indicator bacteria concentrations that suggest eutrophication from increased development or inappropriate fertilizer application. Nutrients increase with increasing development, and are increasing over time in Barton Springs. Some improvements may be occurring to surface water quality in large watersheds over time, but trends need to be verified and causes have not yet been determined.

Nitrogen and phosphorus are nutrients that support the growth of algae and aquatic plants. When elevated levels of nitrogen and phosphorus enter the environment, it causes algae to grow faster than ecosystems can handle. As the algae die and decompose, it can severely reduce or eliminate oxygen in the water, leading to the death of fish and other aquatic life.

Sources of nutrient pollution include:

- Application of fertilizers. Synthetic nitrogen and phosphorus fertilizers are often applied in excess of needs. The excess nutrients are lost through surface runoff and leaching to groundwater.
- Urban stormwater runoff. Rainfall events flush nutrients from residential lawns and impervious surfaces into adjacent creeks.
- Irrigation with potable water. In general, nutrient concentrations in potable water, or treated drinking water, are higher than the median creek levels.
- Soil erosion. Most Austin-area soils have excessive levels of available phosphorus, which may be released into the environment as bank erosion occurs

4.2 Base Map

The Base Map is an ArcGIS document that organizes and displays data related to excess nutrients, including both potential sources (e.g., golf courses, athletic fields) and potential solutions (e.g., creek buffers, structural controls). The purpose of the Base Map is not only to provide a clearinghouse of related data, but also to allow staff to spatially correlate potential sources and solutions with the problem scores for individual EII reaches.

This data was identified through meetings with internal department stakeholders and is a combination of existing GIS data as well as newly-created GIS data. Upon completion, the Base Map was reviewed by the internal stakeholders and additional updates were completed.

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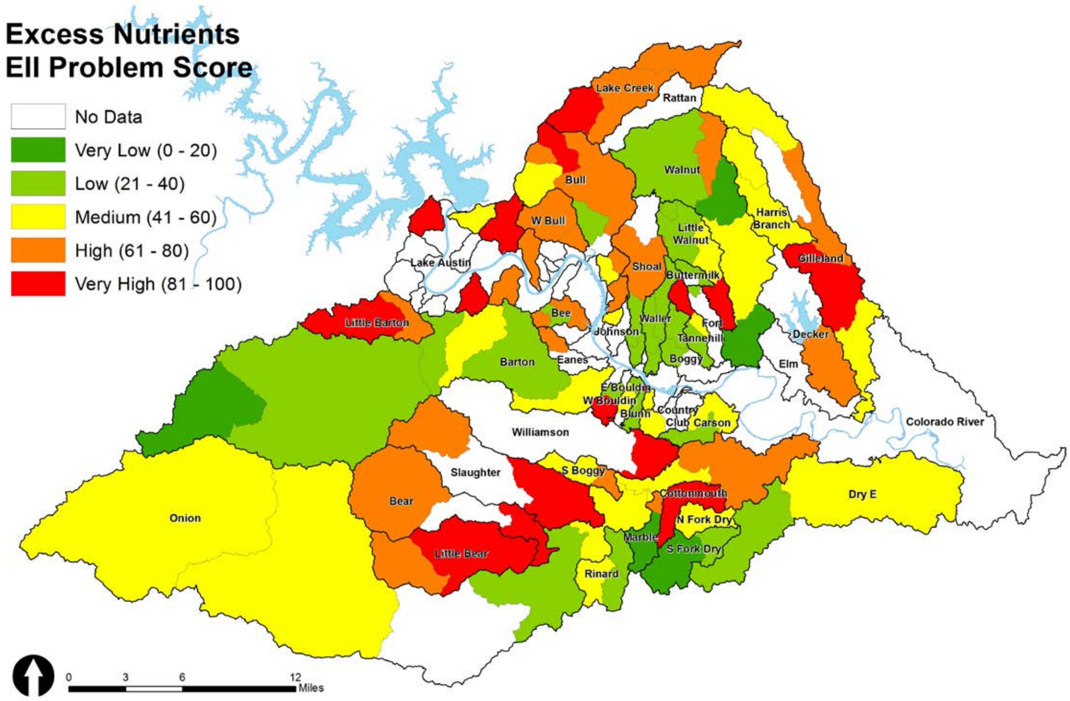

4.3 Actions

Introduction

The Watershed Protection Department addresses water quality degradation associated with excess nutrients using a three-tiered approach of programs, regulations, and capital improvement projects.

Examples of programmatic solutions include public education (see Grow Green), research (see Case Study), and passive restoration of riparian buffers. For a more detailed discussion of passive restoration, see the Poor Riparian Vegetation Watershed Profile.

Examples of regulatory solutions include requirements for structural stormwater controls, critical environmental feature setbacks, stream buffers, and Integrated Pest Management Plans. For a more detailed discussion of stream buffers, see the Poor Riparian Vegetation Watershed Profile. For a more detailed discussion of Integrated Pest Management Plans, see the Toxins in Sediment Watershed Profile.

Examples of capital improvement projects include water quality pond retrofits as well as riparian restoration projects. Riparian restoration techniques are discussed in more detail in the Poor Riparian Vegetation Watershed Profile.

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Grow Green

The City's Grow Green program, subtitled "An Earthwise Guide to Landscaping," was launched in 2000 to reduce landscaping chemicals in Austin's creeks, lakes and aquifer. Grow Green is a partnership between the City of Austin and the Texas AgriLife Extension Services. All materials are designed by the City using the technical expertise of the Texas AgriLife Extension Services. The City manages the program within the City limits with Extension handling the rest of Travis County.

Grow Green offers 23 fact sheets that help identify and solve pest and disease problems and provide general landscaping design, installation and maintenance recommendations. It offers a Native and Adapted Plant Guide that recommends 200 plants that not only survive, but thrive in Central Texas. It also provides workshops and technical information to nursery sales associates so that they can better serve their customers. All materials are offered free to Austin citizens and garden centers Educational messages were developed that follow the City's Grow Green program recommendations.

Grow Green is based on Integrated Pest Management (IPM) principles that encourage problem prevention and identification, followed by least toxic control options. Chemicals are recommended only as a last resort. Strategies were developed that would overcome obstacles for homeowners in adopting earth-wise landscaping practices. One such strategy was to help negate the higher cost of organic fertilizer. Grow Green promotes results from a greenhouse study conducted by Texas A&M and funded by the City of Austin that found that using half as much fertilizer, half as often as recommended on the bag, could offset the higher cost of naturally slow-release organic products.

The City simplified the existing Grow Green guidelines into three main messages for the educational campaign, known as The Big 3:

1. Don't over-fertilize.
2. Don't kill the good guys.
3. Tolerate a few weeds.

The messages encourage homeowners to use landscaping chemicals responsibly. The "don't over-fertilize" message describes the water quality impacts from excess nutrients in streams and then gives specific information on the amount of the product that should be applied (1/2 lb/ft2) while encouraging the use of organic or natural products that are inherently slow release. Additionally, the fertilizer message gives practical reasons why reduced fertilizer use translates to less mowing, less watering, fewer turf diseases and reduced costs for homeowners.

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Help Reduce Pesticides in Our Waterways

Avoid Weed and Feed
(any combined fertilizer + weed killer)

- Spreading a weed killer over the entire lawn is usually excessive
- Combined products are rarely a good mix – the best time to treat weeds is NOT usually the best time to fertilize

Maintain a healthy lawn to out-compete weeds

If you need to fertilize...

- Use a straight fertilizer – not one combined with a pesticide
- Choose an organic or other slow release fertilizer – they leach fewer chemicals into our groundwater
- Measure your lawn size, not your property size, before applying chemicals
- Don't bag your grass clippings – if you leave them on the lawn, you only need half as much fertilizer, half as often as listed on the bag
- Fertilize around April 15 (or after your lawn has been mowed two times)
- If necessary, fertilize in early October (but only if the lawn looks unhealthy)
- Water in gently – don't fertilize before a heavy rain

To get rid of weeds...

- Use a hoe, weed popper or your hand to remove weeds; remove when they are small and when the soil is moist
- Remove weeds regularly before they flower or go to seed
- Look for the Grow Green Weed fact sheet at nurseries or www.growgreen.org to identify your weeds – many can be "mowed away" or easily hand-pulled
- If you must use an herbicide,
  - Spot-treat with one that lists your problem weed on the label
  - Choose a post-emergent product (after weed is visible) – it allows you to treat only where you know there's a problem and to properly identify the weed

Structural Stormwater Controls

Structural water quality controls may consist of engineered and constructed filters, chambers, basins, or ponds which are designed to treat stormwater runoff by settling, filtration, flotation, absorption, and/or biological processes. The Land Development Code establishes the need for structural controls to enhance water quality and the Environmental Criteria Manual provides guidelines for both the design and long-term maintenance of these facilities. Structural controls include: biofiltration, porous pavement, rain gardens, rainwater harvesting, retention irrigation ponds, sedimentation filtration ponds, vegetated filter strips, and wet ponds.

Sedimentation/filtration systems are the primary stormwater treatment device used in Austin. Runoff is first diverted into a sedimentation basin, where particulate pollutants are removed via gravity settling, followed by filtration through an 18" layer of sand. These systems achieve relatively low removal rates for dissolved nutrients, with around 30% removal of total nitrogen. The other types of controls listed above would provide at least an equivalent level of treatment. However, SOS-compliant controls such as retention irrigation ponds have been shown to remove up to 100% of dissolved nutrients.

In March 2011, the University of Texas Center for Research in Water Resources (CRWR) completed a study of biofiltration ponds to assess the role of plants in nutrient removal and to compare the pollutant removal effectiveness of biofiltration systems containing different media, plant species and designs. The results of this study showed a significant improvement in nutrient removal with the

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presence of plants and a submerged zone with a carbon source in the filter. The columns without plants were found to export up to twice the nitrate/nitrite input, whereas the columns with plants showed significant removal of all nutrients (Nitrate 30-50%, Total Kjeldhal Nitrogen 65-85%, Total Phosphorus 80-90%).

Critical Environmental Feature Setbacks

Critical environmental features are features that are of critical importance to the protection of environmental resources, and include bluffs, canyon rimrocks, caves, sinkholes, springs, and wetlands. Development must provide a setback of 150 to 300 feet from all protected features. In addition, drainage patterns for proposed development must be designed to protect critical environmental features from the effects of runoff from developed areas, and to maintain the catchment areas of recharge features in a natural state. Many of these features (e.g., sinkholes) provide a direct conduit to the Edwards Aquifer and thus it is imperative to ensure that pollutants such as excess nutrients are not directed to these sensitive features.

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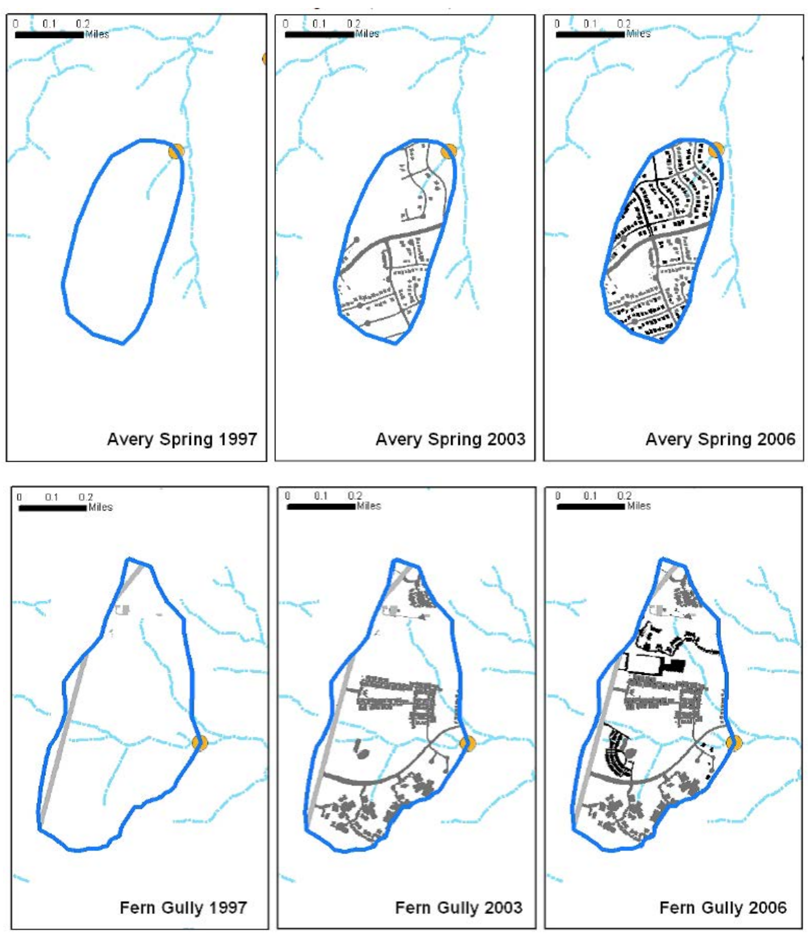
4.4 Case Studies

Linking Nutrients and Impervious Cover

Karst springs in the Canyon Creek and Avery Ranch subdivisions were monitored before, during, and after construction of residential homes with some commercial development. The objective of the monitoring program was to track trends in spring chemistry with changing land use in source area and compare the water quality impact of different water quality regulations after development. Groundwater chemistry, particularly ions, changed in correlation with increasing development.

A comparison was made between the spring chemistry data collected from a newly developing subdivision that was permitted under an enhanced development agreement known as a Planned Unit Development (PUD) and an older subdivision that was built-out under a less restrictive Municipal Utility District (MUD) agreement to determine if differences in water chemistry could be seen. Spring data collected seemed to indicate that only slight differences could be detected in groundwater chemistry results between the two subdivisions. This suggests that water quality benefits provided by surface water quality controls had little effect on groundwater quality within the subdivisions. Additional data is needed to test this hypothesis.



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4.5 Supporting Documentation

Trends in Barton Springs water quality: http://www.ci.austin.tx.us/watershed/publications/files/SR-10-06%20Karst%20Springs%20Temporal%2020091.pdf and http://pubs.usgs.gov/fs/2011/3035/

Increasing nutrients in groundwater with increasing impervious cover: http://www.ci.austin.tx.us/watershed/publications/files/SR-07-05%20Avery_CanyonCreek_Rural_to_Urban_GW.pdf

Limouzin, M., Lawler, D. and M.E. Barrett. 2011. Performance Comparison of Stormwater

Biofiltration Designs. CRWR Online Report 10-05.

Final Report on Austin Lawn and Garden Chemical Education Campaign: http://www.tceq.texas.gov/assets/public/compliance/monops/nps/projects/77054_FinalReport.pdf

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5 Litter

5.1 Problem Score Calculation

Litter = 100 - (Litter EII)

Litter EII component scores collected for the aesthetics subindex are subtracted from 100 to identify reaches with litter problems. EII litter scores are based on a visual assessment of litter quantity and type at the representative monitoring site for each reach.

Urban environments offer a multitude of inputs to aquatic systems that do not exist in natural systems. One unsightly input is floatable trash. The most common types of floatable trash found in our streams are Styrofoam/plastic cups and containers, random plastic and foam objects, cans, wrappers and other food containers. These objects appear in large quantities immediately after rain events indicating that there are large quantities of trash laying on the ground or that there are hidden reservoirs of trash awaiting transport to water bodies.

Litter has a number of negative effects on its surrounding environments. It is aesthetically displeasing, causing users of highly littered areas, such as parks or rivers, to view the area negatively or decrease support for the area. It can also have a negative effect on wildlife, causing entanglement, or harm through the ingestion of litter. It is dangerous to humans in terms of lacerations from sharp objects which can put the injured person at risk of infection or tetanus. Depending on the type of pollutants contained in the litter, contamination to groundwater and harm to humans and wildlife through bioaccumulation can occur. Litter and debris also has the potential to clog and obstruct existing drainage infrastructure, creating stormwater conveyance issues.

5.2 Base Map

The Base Map is an ArcGIS document that organizes and displays data related to litter, including both potential sources (e.g., special events, storm drain outfalls) and potential solutions (e.g., cleanup locations, street sweeping routes). The purpose of the Base Map is not only to provide a clearinghouse of related data, but also to allow staff to spatially correlate potential sources and solutions with the problem scores for individual EII reaches.

This data was identified through meetings with internal department stakeholders and is a combination of existing GIS data as well as newly-created GIS data (e.g., geocoded addresses). Upon completion, the Base Map was reviewed by the internal stakeholders and additional updates were completed.

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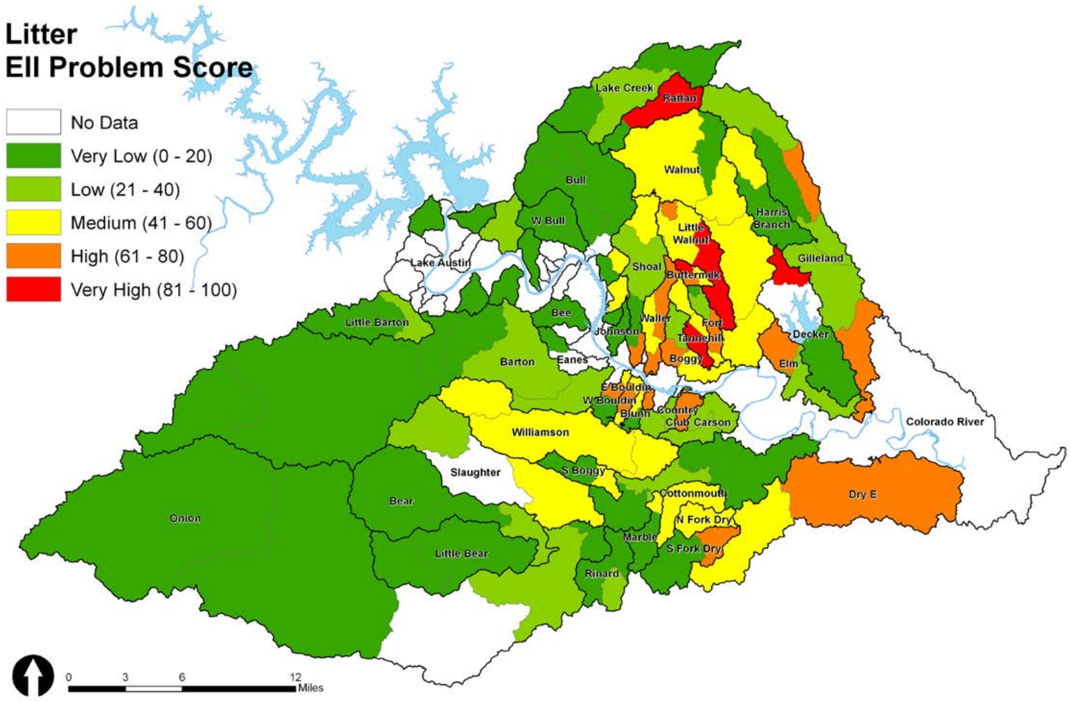

5.3 Actions

Introduction

The Watershed Protection Department addresses litter using a three-tiered approach of programs, regulations, and capital improvement projects. Examples of programmatic solutions include public education (Let's Can It!), operations, and maintenance (Street Sweeping, Infrastructure and Waterway Maintenance), and partnerships (see Keep Austin Beautiful). Examples of regulatory solutions include the Single-Use Carryout Bag Ordinance. Structural water quality controls required for development are also able to reduce the amount of trash and debris entering waterways and storm drains (Best Management Practices). Examples of capital improvement projects include the use of stormwater BMPs to capture trash and debris (Manufactured Treatment Device Pilot Study).

Litter Education – Let's Can It!

The Let's Can It! Austin campaign is a partnership between the Watershed Protection Department, Austin Resource Recovery, and local non-profits to raise awareness about the impact of litter on our environment and to get citizens involved in putting trash in the can. The program includes a thirty second television spot, radio ads, webpage – www.LetsCanItAustin.org, semi-permanent interpretive signage by trash booms on Lady Bird Lake, interpretive signage that volunteers can display during cleanups to educate other volunteers and people passing by, educational activities, and promotion of volunteer opportunities.

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In FY12, the message was also promoted via advertising on and inside Capital Metro buses in both English and Spanish. After the advertising contract was complete the interior signs were saved and shared with teachers to display in their classrooms, and WPD's pollution prevention and reduction team has distributed the signs in parts of town that have experienced a high volume of litter complaints.

The Let's Can It! Austin messaging is incorporated into youth education by using a litter lifeline with the LCIA branding in Earth School presentations. In the 2011-2012 school year, more than 5,000 fifth grade students experienced Earth School. Additionally, our partners at Keep Austin Beautiful have a free activity kit lending program and feature LCIA branding in their lessons about litter. www.KeepAustinBeautiful.org/ActivityKits

Extending the program beyond awareness, the webpage also includes calls to action and encourages citizens to get involved with volunteer programs like marking storm drains or participating in a volunteer cleanup.

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Keep Austin Beautiful

Since 1985, Keep Austin Beautiful (KAB) has engaged the Austin community to remove litter from neighborhoods, creeks, and public spaces in collaboration with the community while raising awareness about the impact of litter. In 2012, more than 18,000 volunteers contributed more than 35,400 hours of service and removed 76.7 tons of trash and debris to clean and beautify the city.

Cleanup efforts stem from one-time events where KAB identifies areas in need, provides cleanup supplies, coordinates trash collection, recruits volunteers, and leads trainings. Through the Adopt-a-Creek program, groups are making lasting commitments to preserve and improve an adopted waterway by conducting 4 creek cleanups per year over a ¼ mile stretch for at least 2 years. With KAB tools, seeds, and guidance, adopters are moving far beyond cleanups; they are taking action to remove invasive species, plant natives, and control erosion, restoring creeks to a more natural riparian state.

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KAB's Clean Lady Bird Lake initiative organizes large-scale cleanups every other month and a Rapid Rain Responder initiative to tackle trash washing into the lake. Volunteers are mobilized at over 13 sites every other month, picking up trash along the shoreline and from watercrafts on Lady Bird Lake. Then every April thousands of volunteers come together for Clean Sweep, a citywide service day spanning 140 project sites resulting in over 25 tons of trash removed.

Best Management Practices (BMPs)

Water Quality Controls

Development in the City of Austin is required by the Land Development Code to capture, treat, and isolate the first flush of runoff during a storm event. This allows trash and debris to settle out within the sedimentation basin or the splitter box itself, preventing litter from ending up in downstream waterways or storm drains. However, frequent maintenance is important to ensure that the litter accumulating within the pond does not obstruct flow and result in stormwater runoff bypassing the control.

Trash Booms

There are three floating trash booms located on Lady Bird Lake that play an integral role in keeping the lake clean. The locations are at the mouths of Shoal Creek, West Bouldin and at Blunn Creek. Each site consists of one boom, made of plastic material that floats at the water surface and extends across the width of the creek to trap floating materials flowing toward the mouth of the creek. Each boom is anchored on either shoreline to maintain its position in the creek. Sites are selected for the placement of trash booms based on the ability to access the site in a safe and secure manner; the amount of public access to the creek; the impact of adjacent urban land use activities; and whether the site demonstrates suitable conditions for boom deployment and cleaning activities.

The systems capture the trash and debris that washes down these urban creeks during storm events. Thirty-two to forty tons of trash and debris are removed from the three booms annually. The booms

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are addressed weekly or after major storm events by Field Operations crews. FOD crews remove all trapped floating material using nets that reach the middle of the creek, allowing removal from both sides of the creeks. Heavier material such as wet wood is pulled to the shorelines and removed with mechanical equipment. The material removed from each site is loaded into City dump trucks and hauled to an acceptable local landfill.

Street Sweeping

Routine street cleaning in the City of Austin is the responsibility of the City's Austin Resource Recovery (ARR) Department. The City of Austin Street Cleaning Program targets the cleaning of City streets in all areas within the City limits for removal of trash, litter, and dirt that has collected in the streets and gutters for health, safety, aesthetic, and water quality reasons. Each year, this program cleans over 5,000 curb miles of streets in Austin and collects over 6,300 tons of trash, leaves, debris, and dirt from impervious roadway surfaces. The Central Business District is swept daily to maximize removal efficiencies. Residential curbed streets are swept on an average frequency of once every two months. Other areas are swept on varying schedules depending on traffic and need.

Litter Control

The Litter Control Program of the City of Austin is the responsibility of Austin Resource Recovery's Litter Abatement Division. The Litter Control Program is implemented within the City limits and has established the following goals:

- Litter containers in the downtown area will be emptied of accumulated litter daily
- Litter crews will remove litter from uncurbed streets, uncurbed right-of-ways and other City property as needed
- Illegal dumping of trash and waste material on public property will be removed as necessary
- Dead animals on roadways will be removed, within 24 hours of being reported, six days per week
- Brush and bulk items will be collected on a scheduled basis each year from residences, so that such items do not get dumped along city watercourses
- Street cleaning crews will remove trash, litter, and dirt that has collected in the streets and gutters on a scheduled basis (see Street Sweeping)

Infrastructure and Waterway Maintenance

The City's stormwater conveyance system is composed of natural and engineered creeks and channels, a network of drainage pipelines, and structural stormwater management controls. Watershed Protection's Field Operations Division (FOD) is responsible for the maintenance of this system, which includes a variety of activities to ensure conveyance for stormwater runoff. FOD

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staff removes excessive vegetation debris and obstructions, including trash and debris, from open channels and waterways, culvert and bridge locations. The frequency of maintenance activities varies from creek to creek. FOD personnel also maintain storm drain pipes and inlets. They inspect, clean and repair the system as needed throughout the year to maintain proper operation and conveyance of stormwater runoff. Specific activities include:

- Remove debris and excessive vegetation from approximately 30 miles of open channels to maintain and improve flood flow conveyance and improve water quality.
- Remove 200+ tons of litter, trash and debris from Lady Bird Lake
- Remove vegetation three times a year from 200 residential detention and water quality basins.
- Inspect 1,200 water quality basins that are associated with commercial activity once a year to enforce compliance with City Code.
- Clear at least three miles of open waterways of sediment and obstructions in order to maintain flood flow conveyance, minimize erosion and improve water quality.
- Remove debris, sediment, vegetation and obstructions from at least 500 culvert and bridge locations in order to maintain flood flow conveyance and improve water quality.
- Clean at least four miles (21,120 ft.) of the storm drain pipe system annually to maintain flood flow conveyance and improve water quality.
- Clean at least 2,500 storm drain inlets to maintain flood flow conveyance and remove collected sediment and other pollutants.

Single-Use Carryout Bag Ordinance

On March 2, 2012, the Austin City Council unanimously approved the Single-Use Carryout Bag Ordinance, which went into effect in March 2013. The ordinance regulates the types of carryout bags business establishments in Austin can distribute and encourages a shift to reusable bags. Those bags include:

- Cloth, fabric or other woven bags, with handles
- Plastic bags that are at least 4 mil (.004 inches) thick, with handles
- Paper bags made of at least 40% recycled content, with handles

With this ordinance, the City expects to see a reduction in plastic bag litter, as Austin shoppers shift to using reusable bags. Since passage of the ordinance, the department distributed over 25,000 reusable bags and will continue this effort in the year to come.

A high-quality reusable bag has the potential to replace 600 thin plastic bags over its lifetime. Austin's Single-Use Carryout Bag Ordinance is not a ban on all plastic bags, but it will drastically reduce the number of thin plastic bags that harm our environment, generate unsightly litter, and wind up in area landfills.

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In its evaluation of litter in America, a Keep America Beautiful study found that since 1969, while metal, glass, and paper litter decreased by over 80% in each case, plastic litter increased by a staggering 165%. The study also found that storm drains were among the most littered areas. This is an especially important concern for the City of Austin because we have numerous creeks that flow into Lake Austin, Lady Bird Lake, and the Colorado River, each of which not only draw tourists to the area, but also help us manage stormwater during major rains.

Plastic bags pose a heightened threat to our water quality because of their physical attributes. Aquatic animals, like the turtles and ducks in Lady Bird Lake, mistake the floating plastic bags as food. If they ingest the bags, they end up suffocating, choking, or starving to death. Since plastic bags are made of petroleum, they slowly release toxins as they photo-decay, negatively impacting our water quality. Due to their thin, light weight, durable quality, plastic bags float on the water's surface, blocking out sun light, decreasing oxygen levels, and negatively impacting natural food cycles. When Austin experiences storms, runoff washes plastic bags and other forms of litter into our storm drains. When our storm drain systems are overwhelmed or clogged by litter and debris, surrounding properties are impacted by localized flooding.

Litter Intensity and Sources Index (LISI) Tool

The purpose of this project is to determine a methodology to accurately and precisely survey litter in Austin watersheds, in hopes of revealing original sources and more efficiently managing litter control efforts. The Litter Index Field sheet will accomplish the following objectives:

- Develop a methodology that tracks litter spatially by scoring the overall litter problem at a given location and comparing that score to other locations.
- Classify litter items into categories and score those categories based on the abundance (or lack) of those items at a given location.
- Identify potential sources of litter at surveyed locations.

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Litter Index Field Sheet

Date:____________ Watershed Name:____________________ Start & End Times:________________

# of Observers & Contact Info:________________________________

Location (nearest cross streets, GPS, address, etc.):________________________________

Score each category of litter below using the following scoring numbers:

Not Present	Present, Not Significant	Significant Presence	Abundant	Extremely Abundant
0	1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20

For descriptions of typical items found in each category, see the reverse side of this page.

Categories	Score	Categories	Score	Categories	Score
Automotive Debris		Bikes, Toys & Sports Items		Beverage Containers	
Construction & Demolition Debris		Miscellaneous Large Items		Take-Out & Fast Food	
Appliances & Machinery		Clothing & Fabrics		Non Take Out Snack Containers	
Furniture & Furnishings		Plastic Bags		Personal Hygiene Products	
Electronic Waste		Packaging Materials		Tobacco Products	
Yard & Landscaping Waste		Printed Paper Items		Miscellaneous Small Items	

Please rank the overall condition of this site based on total litter present (circle a number):

None	Present, Not Significant	Significant Presence	Abundant	Extremely Abundant
0	1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20
No litter is present	An occasional item or two throughout, but not readily observed *AND* - there are no pockets of accumulated litter.	Litter is not continuous, but is fairly evident throughout *OR* – very little litter throughout but with a few small pockets of accumulation.	Almost continuous litter throughout with a few gaps *OR* – litter is not continuous but with some large pockets of accumulation.	Litter is totally continuous throughout *AND* – several large pockets of accumulation

Can you identify any sources contributing to the litter problem at this site?

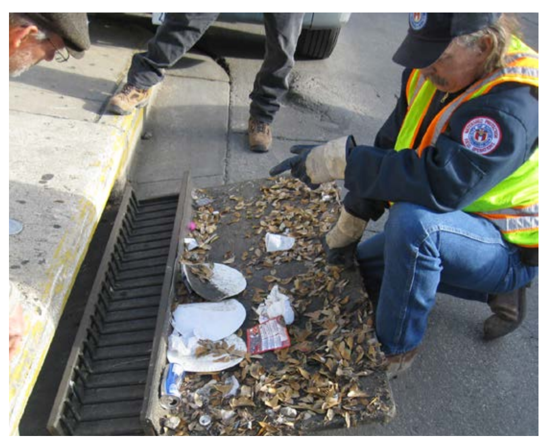
☐ A recent illegal dump site ☐ An older illegal dump site ☐ Storm or Flood debris
☐ Overflowing trash cans or dumpsters ☐ Homeless camp site ☐ Wind
☐ Roadside littering ☐ Recreational activities ☐ I am not sure
☐ Other (please explain).

Categories	Typical Items in Each Category
Automotive Debris	Motorized vehicles and/or parts, mufflers, hubcaps, lights, windows, oil/air filters, tires, empty oil/solvent cans, car batteries, etc. **If car/boat batteries or any hazardous waste fluid spills are present, please call the Spills Response Team at (512) 974-2550 and note your observation somewhere on this sheet.**
Construction & Demolition Debris	Lumber, concrete, asphalt, bricks, cinder blocks, insulation, shingles, tiles (floor, counter or roof), drywall, piping, rebar, nails, fasteners, silt fences, debris fences, piled sand or fill material, renovation-related materials, doors, windows, frames, siding from buildings or attached fixtures (such as sinks).
Appliances & Machinery	Washing machines, dryers, dishwashers, stoves, refrigerators, air conditioners, vacuums, fans, lawn equipment, or any other home or business appliances.
Furniture & Furnishings	Beds, mattresses, couches, chairs, floor cabinets, dressers, carpets, rugs, lamps, etc.
Electronic Waste	Laptops, computer monitors/towers, televisions, radios, phones, light bulbs, fluorescent light tubes, copiers, scanners, batteries, etc. *Note: Car/boat batteries DO NOT go here and should be listed under Automotive Debris.
Yard & Landscaping Waste	Grass cuttings, raked leaves, clearly cut tree/shrub branches, discarded plants, landscaping/potting soil, etc. *Note: Lawn equipment DOES NOT go here and should be listed under Appliances and Machinery.
Bikes, Toys & Sports Items	Bicycles, tricycles, big wheels, children/pet toys, and any type of ball or sports item. *Note: Electronic games or batteries DO NOT go here and should be listed under Electronic Waste.
Miscellaneous Large Items	Any item too big to fit into a large trash bag that does not appear to fit into any other categories on this sheet, shopping carts, wooden pallets, tents, etc. Please list significant items found here.
Clothing & Fabrics	Clothing or clothing accessories, purses, scarves, shoes, hats, belts, blankets, sheets, linens, etc.
Plastic Bags	Any type of plastic bag, grocery, retail, garbage bags, or torn pieces of plastic bags, etc. *Note: Plastic material not from a bag DOES NOT go here (Ex. Bubble wrap goes in Packaging Materials). Also contents of a plastic bag should be recorded elsewhere.
Packaging Materials	Corrugated boxes, paperboard, packing cases, plastic bubble wrap, styrofoam packing peanuts, containers used for shipping, etc.
Printed Paper Items	Newspapers, magazines, phone books, junk mail, flyers, business/school papers, bill statements, etc.
Beverage Containers	Cans, bottles, boxes, cartons or pouches used for any beverage including alcohol. Caps, lids, six-pack rings, beverage cases or other drink packaging. *Note: Styrofoam/paper cups DO NOT go here and should be listed with Take-Out & Fast Food.
Take Out & Fast Food	Fast food packaging, disposable cups, plates, trays, utensils, condiment packaging, food waste, napkins, straws. *Note: If in a plastic bag, record the contents here and the bag in Plastic Bags.
Non-Take-Out Snack Containers	Snacks packaging, candy or gum wrappers, energy bars, potato chip bags, vending machine items, etc.
Personal Hygiene Products	Toilet paper, feminine hygiene, Q-tips, condoms, diapers, make-up/hair product containers, toothpaste, etc.
Tobacco Products	Cigarette/cigar butts, smokeless tobacco products, tobacco product packaging, lighters, matches, etc.
Miscellaneous Small Items	Any item small enough to fit in a large trash bag that does not appear to fit into any other categories on this sheet; fishing tackle, string, rope, etc. Please list significant items found here:

The primary use of the tool will be for WPD staff to quantitatively assess litter, document sources, and compare locations. For example, staff can use the LISI in response to citizen complaints. Staff examined the amount of training necessary for litter tracking to evaluate the potential for expanding the use of the tool to volunteers (e.g., Keep Austin Beautiful), but the study determined that the tool will not be useful as a volunteer data collection form due to discrepancies in scoring.

5.4 Case Studies

Manufactured Treatment Device (MTD) Pilot



This pilot study is being implemented by Watershed Protection to assess the performance of a selected manufactured treatment device (MTD) for trash and pollutant removal from stormwater runoff. In 2009, City management formed a multi-departmental task force to construct a vision for the Seaholm District in the Lower Shoal Creek Watershed. Watershed Protection was asked to recommend solutions to clean up Lower Shoal Creek. With limited space to install stormwater controls, WPD made the recommendation to retrofit the existing inlet boxes with MTDs that would capture trash and debris before draining to the creek. Under contract with WPD, CH2MHill completed a preliminary

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engineering study to analyze a multitude of MTDs for implementation within inlets that drain directly to Shoal Creek in the Seaholm District. Based on a variety of criteria, the MTD recommended by the study was the Bio-Clean High Capacity Curb Inlet Basket.

With preliminary engineering complete, WPD has decided to move forward with a pilot study to (1) assess the performance of the Bio-Clean MTD prior to installation in additional inlets in the project area and (2) assess the performance of the current system of inlet filters and screens. The study will monitor the following performance measures for both proposed and existing systems:

- Maintenance
  - Frequency
  - Time to clean
  - Required Equipment
  - Disposal
  - Safety Concerns
  - Accessibility
- Trash and Sediment Removal Amounts
- Durability
- Hydraulic Performance

At the end of the pilot, staff will be able to define the following parameters:

- Approximate staff hours required to maintain operation of the devices
- Amount of trash and debris removed
- Cost of installation
- Cost of maintenance

If the performance of the MTDs is found to be acceptable, this data will allow WPD to consider whether implementation of additional devices in the project area is feasible with current staffing levels.

WPD is also interested in use of MTDs in the lower Waller Creek District associated with the flood-control tunnel and anticipated revitalization of the creek through this area. For this reason three Bio-Clean MTD installations within Waller Creek watershed will be part of this pilot as well.

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6 Poor Riparian Vegetation

6.1 Problem Score Calculation

Poor riparian vegetation = 100 – [(vegetative protection EII/100)*(riparian width EII)]

The problem score for poor riparian vegetation prioritizes sites with narrow, poor quality riparian zones based on visual assessments from the EII Habitat Quality Subindex surveys. The score could potentially be expanded in the future through the use of the Index of Riparian Integrity to cover a larger spatial extent than EII sampling sites.

Riparian systems provide a suite of ecosystem services including, but not limited to, stabilized stream banks, clean water, wildlife habitat, and groundwater recharge. The more degraded an ecosystem, the more fundamentally altered the basic services will become. A degraded riparian zone is often entirely mowed, which results in bare soil along a stream bank. A lack of vegetation is a visible and primary variable that relates to overall riparian health.

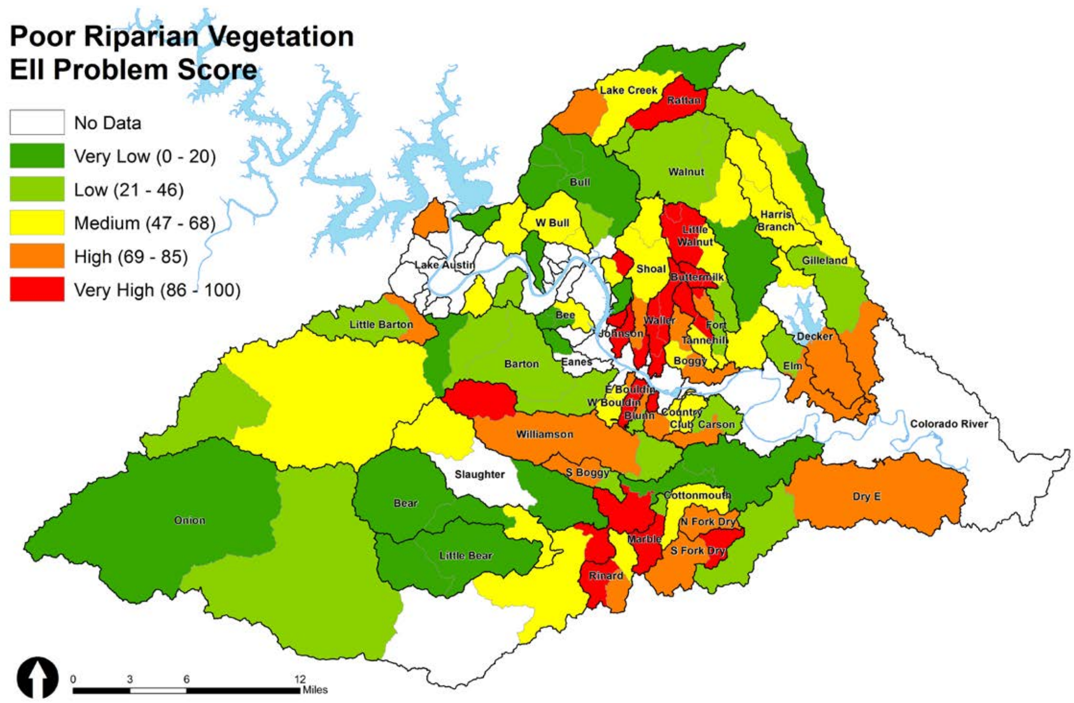
Probably the most important driver of degradation to a riparian zone is the alteration of the natural hydrologic cycle that occurs from the urbanization of a watershed. This change or degradation in rain infiltration, flashy flows, and baseflow essentially disconnects the banks and buffers from the stream and the water table. The types of vegetation that thrive in wet, active floodplains cannot survive in this state and the result is a degraded, abandoned, or upland vegetative community.

After hydrology, the next most important factor that degrades riparian areas is alteration of the mature vegetative communities that evolve in these areas. This occurs primarily via human intervention (i.e. mowing, agriculture, or development). These activities remove the original vegetation, and degrade and compact the soil. When repeated over decades, this makes it very difficult to “replant” a healthy riparian vegetative community.

6.2 Base Map

The Base Map is an ArcGIS document that organizes and displays data related to poor riparian vegetation, including both potential sources (e.g., impervious cover, vegetation control) and potential solutions (e.g., riparian restoration, stream buffers). The purpose of the Base Map is not only to provide a clearinghouse of related data, but also to allow staff to spatially correlate potential sources and solutions with the problem scores for individual EII reaches.

This data was identified through meetings with internal department stakeholders and is a combination of existing GIS data as well as newly-created GIS data. Upon completion, the Base Map was reviewed by the internal stakeholders and additional updates were completed.



6.3 Actions

Introduction

The Watershed Protection Department addresses poor riparian vegetation using a three-tiered approach of programs, regulations, and capital improvement projects.

Examples of programmatic solutions include passive restoration projects (see Grow Zones) and maintenance practices (see Field Operations). Examples of regulatory solutions include requirements for new development to setback from waterways by providing a Critical Water Quality Zone (see Stream Buffers). Examples of capital improvement projects include active restoration projects (see Riparian Zone Restoration and Willowbrook Reach Case Study). Streambank stabilization projects are completed to address erosion problems, but improve poor riparian vegetation as well. These projects are discussed in more detail in the Watershed Profile for Unstable Channels.

Stream Buffers

The Critical Water Quality Zone is a stream setback established by Code that prohibits development other than limited low-impact uses such as parks, trails, and crossings. The geometry of the setback varies with the size of the drainage area and the watershed classification (e.g., Suburban). The secondary Water Quality Transition Zone buffer requires a lower intensity of development than in the "uplands" areas upslope of the buffers, depending on the watershed classification. By promoting healthy soils and vegetation along the creek corridor and allowing the stream adequate space to

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migrate over time, stream buffers benefit a number of Master Plan goals, including:

Water Quality

- Filters & absorbs runoff for water quality
- Removes sediments, nutrients, metals, toxics, and other pollutants
- Slowly releases stored water and maintains creek baseflow
- Moderates water temperature
- Provides critical aquatic and terrestrial habitat

Erosion Control

- Protects bank integrity with vegetation
- Prevents loss of property from erosion
- Provides space for future channel migration
- Minimizes channel modifications

Flood Protection

- Promotes “sponge” effect with soils, vegetation, microtopography, and overbank storage
- Slows “time-of-concentration” until peak flow occurs
- Allows natural adjustment of floodplain geometry over long periods of time to ensure right sizing
- Allows for margin for error and distances public from flash flooding

Operations and Maintenance

- Reduces active maintenance (e.g., mowing)
- Reduces need for CIP projects to shore up failing banks and structures
- Reduces citizen complaints for erosion and flood problems
- Provides room for channel work and restoration/retrofit projects when needed

Community Benefits

- Protects adjacent property
- Maintains lower drainage utility fees
- Increases surrounding property values
- Provides space for greenways and trails
- Provides opportunities for recreation and connectivity, improving community health
- Provides educational opportunities
- Provides space for community gardens and local food production
- Preserves or allows restoration of natural and historic character

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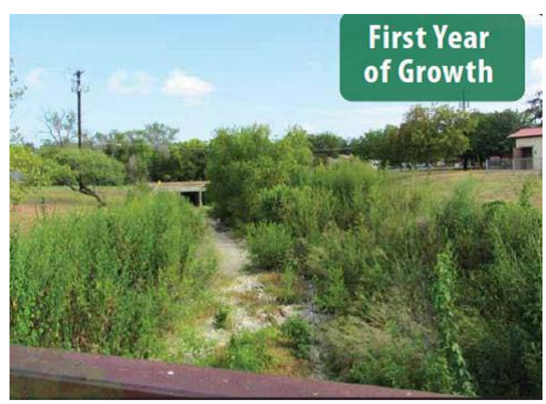
The Austin City Council initiated an amendment to the Land Development Code in January 2011 to improve creek and floodplain protection; prevent unsustainable public expense on drainage systems; simplify development regulations where possible; and minimize the impact on the ability to develop land. The effort was the first of its kind since the City's Comprehensive Watershed Ordinance (CWO) was enacted in 1986. One major cornerstone of the new ordinance is the extension of the Critical Water Quality zone buffer to headwaters streams with 64 acres of drainage citywide. This change will be most significant in the eastern Suburban watersheds, which currently only protect streams up to 320 acres of drainage.

Grow Zones

A "Grow Zone" is an effort to halt mowing along streams and allow the growth of more dense, diverse riparian vegetation. The establishment of Grow Zones will provide many benefits, such as reducing stream bank erosion, improving the area's soil and water quality, increasing wildlife habitat, and slowing down flood waters. The vegetated Grow Zones protect the creek from pollution by filtering the water that flows to creeks during a rainstorm. A mature riparian zone can reduce the intensity and spread of wildfires by increasing local shade, soil moisture, and humidity.

The City's Watershed Protection and Parks and Recreation Departments have partnered to improve the health of creeks in several City parks (19 pilot sites). The program decreases the regular mowing along the creek, which allows a more biologically-diverse plant community to grow in place of the existing, degraded turf. Over time, native grasses and, eventually, trees will become established and transform the area into a more natural and beautiful landscape for the enjoyment of park users and nature lovers.



City staff are actively monitoring these sites to document the transition and ensure that the restoration goals are being reached. They are meeting with neighborhood associations, conducting

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educational creek walks for citizens, and posting signs to explain the process. They also developed a Creekside Homes guide with tips on landscaping and pollution prevention. The Grow Zone initiative is an important step in the management of healthy creeks and parks. The community can support Grow Zone projects by adopting a creek (http://www.keepaustinbeautiful.org/Adopt-a-Creek), participating in restoration activities, and educating others about the benefits of these areas.

For more information, visit http://austintexas.gov/department/riparian-restoration.

Riparian Zone Restoration

City of Austin

Riparian Zone Restoration (RZR) is a new initiative designed to increase vegetation quantity and quality along streams as a means of improving water quality. Past and present stream work efforts have been aimed at controlling flooding and erosion with the water quality benefit as an add-on to the more structural channel work. This program focuses more on water quality driven restoration projects, targeting areas in Austin's waterways that will most benefit from healthy riparian vegetation, and collaborating with other mission projects (erosion, flood, utility) to ensure their revegetation components have a clear water quality benefit to Austin's streams.

The Master Plan directs staff to:

1. Protect and improve Austin's waterways and aquifers for citizen use and the support of aquatic life.
2. Improve the urban environment by fostering additional beneficial uses of waterways and drainage facilities.
3. Optimize City resources by integrating erosion, flood and water quality control measures.

This program aims to accomplish these Master Plan missions by creating water quality improvements that also function as wildlife habitat, urban forests with trails and educational opportunities, and by better utilizing the revegetation portion of CIP funds.

There are three generalized approaches to restoring a disturbed riparian environment:

1. Rely completely on passive measures
2. Exclusively adopt active, technical measures
3. Use a combination of both passive and active techniques toward a target goal

Passive restoration requires minimal management and is more cost effective than alternative methods. However, passive restoration is often the slower approach and is more dependent on

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adjacent site conditions. In general, passive restoration that relies on spontaneous succession should be employed when environmental disturbance is not very extreme and no negative results (erosion, water contamination, negative aesthetic perception, etc.) are foreseen. The persistence of undesirable functional states (high stress, low productivity) is an indication that the system may be stuck and will require active intervention to move it to a more desirable state. Understanding when passive versus active restoration approaches are warranted can increase chances of success and reduced project costs.

In order to maximize ecological benefits at the least economical cost it becomes imperative to accurately prioritize sites in need of restoration. By combining the current literature with field investigation/verification, the Watershed Protection Department has developed a riparian restoration site selection framework. Results suggest that combining regional water quality and biological data with site specific evaluations of existing soil and vegetation composition is an appropriate method for allocating restoration resources. Due to the small budget, large size, and public land application of most riparian restoration projects, stakeholder support has also been identified as a key component in guiding site selection. Without the ability to pragmatically select sites to receive riparian restoration, there is a risk of losing public support.

For an example of a Riparian Zone Restoration project, see the Willowbrook Reach Case Study below.

Note: Since the City cannot regulate riparian zone protection for agriculture under state law, the following voluntary programs and partnerships are recommended as solutions for agricultural uses:

Texas State Soil and Water Conservation Board[2]

The TSSWCB is the lead agency in Texas responsible for planning, implementing and managing programs and practices for preventing and abating agricultural and silvicultural (forestry-related) nonpoint source pollution. In accordance with this responsibility, the TSSWCB administers a certified Water Quality Management Plan (WQMP) Program that provides, through local soil and water conservation districts (SWCDs), for the development, implementation, and monitoring of individual WQMPs for agricultural and silvicultural lands.

A WQMP is a site-specific plan designed to assist landowners in managing nonpoint source pollution from agricultural and silvicultural activities. WQMPs are traditional conservation plans based on the criteria outlined in the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) Field Office Technical Guide (FOTG). The FOTG is the best available technology and is tailored to meet local needs.

2 Summary of program (and LCRA Creeksite Conservation Program below) taken from *Implementation Plan for One Total Maximum Daily Load for Bacteria in Gilleland Creek*

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A WQMP includes appropriate land treatment practices, production practices, management measures, technologies, or combinations thereof. This approach to preventing and abating nonpoint source pollution (including bacteria) uses a voluntary approach while affording the landowner a mechanism for compliance with the state's water quality standards.

Grazing management examines the intensity, frequency, duration and season of grazing to promote ecologically and economically stable relationships between livestock and forage species. The distribution of grazing animals is managed to maintain adequate and desired vegetative cover, including on sensitive areas like riparian corridors. Livestock distribution is managed through cross-fencing, alternate water sources, supplemental feed placement, and shade or cover manipulation. The expected forage quality, quantity, and species are analyzed to plan for an appropriate forage-animal balance. Grazing management systems plan for potential contingencies such as severe drought, wildfires, or flooding in order to protect the resource, protect grazing animals, and reduce economic risk.

LCRA Creekside Conservation Program

Since 1990, the LCRA Creekside Conservation Program has promoted reduction of soil erosion and abatement of nonpoint source pollution through the voluntary implementation of BMPs and conservation plans by landowners across LCRA's statutory district. A Creekside Conservation Program conservation plan is site-specific to individual agricultural lands directly along or adjacent to riparian areas and is developed in collaboration with NRCS and local SWCDs. All BMPs used in conservation plans are subject to NRCS technical standards described in the FOTG, and include, but are not limited to cross fencing, slope stabilization, vegetative buffers along creeks, range seeding and pasture planting, alternative water source development for livestock, and rotational grazing systems.

Landowners may be reimbursed up to 50% of the actual cost of the pre-approved projects through the program. Since 2004, the Creekside Conservation Program has been supported through CWA §319(h) nonpoint source grants from TSSWCB. These grants have provided funds to LCRA for the provision of technical and financial assistance to program participants. By utilizing LCRA funds leveraged with the §319-funds, the maximum cost-share amount reimbursable is up to $20,000 per individual landowner. While not required for participation in the Creekside program, landowners are encouraged to obtain a WQMP certified by TSSWCB.

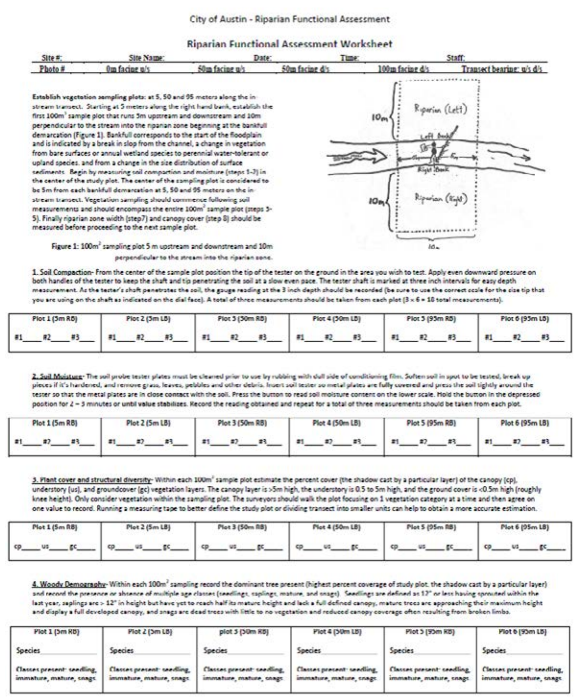
Riparian Functional Assessment

In an effort to understand how various levels of management have impacted the ecological function of urban riparian zones, City staff developed methodology for a Riparian Functional Assessment (RFA) and performed assessments at 28 site locations in the spring of 2012. Sites were categorized into degraded (history of vegetative control and disturbance) and reference (minimal vegetation management and anthropogenic disturbance) in order to determine which of the 15 measured RFA parameters could be used to monitor improvements to riparian zone function as a result of vegetative restoration over time. The following seven parameters were found to be significant:

1. Soil compaction
2. Soil moisture
3. Riparian zone width
4. In-stream canopy cover
5. Plant cover and structural diversity
6. Hardwood demography
7. Seedling recruitment

Results suggest that monitoring for changes in these seven parameters over time will allow managers to accurately assess if ecological function is being improved following restoration activities. Being able to prove restoration project success is vital to maintaining public support and funding for future riparian restoration projects.

Overall RFA scores, based on the seven parameters, were significantly higher in reference than at degraded sites. These differences are directly related to the vegetation management activities occurring in and around the riparian zone. Currently, all of the degraded locations have been incorporated into the Riparian Zone Restoration program (see above). The Grow Zones will receive annual Riparian Functional Assessments in order to determine if the successional trajectory of vegetation is improving ecological function. Over time the calculated RFA scores of the degraded sites should mimic that of the reference locations. Parameters such as soil moisture and compaction and riparian zone width can change relatively rapidly and positive changes are expected after a few growing seasons. Overall plant cover and structural diversity along with in-stream canopy cover are slower to respond, with changes not expected for at least 5-10 years. Hardwood demography and seedling recruitment can also change rapidly but are more interpretive and allow for managers to adaptively manage a site over time. For example, if undesirable species such as exotic, upland, or annual species dominate the recruitment class after the first few growing



City of Austin - Riparian Functional Assessment

Riparian Functional Assessment Worksheet

Site #: Site Name: Date: Time: Staff:

Photo # 0m facing u/s 50m facing u/s 50m facing d/s 100m facing d/s Transect bearing: u/s d/s

Establish vegetation sampling plots: at 5, 50 and 95 meters along the in-stream transect. Starting at 5 meters along the right hand bank, establish the first 100m² sample plot that runs 5m upstream and downstream and 10m perpendicular to the stream into the riparian zone beginning at the bankfull demarcation (Figure 1). Bankfull corresponds to the start of the floodplain and is indicated by a break in slop from the channel, a change in vegetation from bare surfaces or annual wetland species to perennial water-tolerant or upland species. and from a change in the size distribution of surface sediments. Begin by measuring soil compaction and moisture (steps 1-2) in the center of the study plot. The center of the sampling plot is considered to be 5m from each bankfull demarcation at 5, 50 and 95 meters on the in-stream transect. Vegetation sampling should commence following soil measurements and should encompass the entire 100m² sample plot (steps 3-5). Finally riparian zone width (step7) and canopy cover (step 8) should be measured before proceeding to the next sample plot.

Figure 1: 100m² sampling plot 5 m upstream and downstream and 10m perpendicular to the stream into the riparian zone.

1. Soil Compaction- From the center of the sample plot position the tip of the tester on the ground in the area you wish to test. Apply even downward pressure on both handles of the tester to keep the shaft and tip penetrating the soil at a slow even pace. The tester shaft is marked at three inch intervals for easy depth measurement. As the tester's shaft penetrates the soil, the gauge reading at the 3 inch depth should be recorded (be sure to use the correct scale for the size tip that you are using on the shaft as indicated on the dial face). A total of three measurements should be taken from each plot (3 x 6 = 18 total measurements).

Plot 1 (5m RB)	Plot 2 (5m LB)	Plot 3 (50m RB)	Plot 4 (50m LB)	Plot 5 (95m RB)	Plot 6 (95m LB)
#1___ #2___ #3___	#1___ #2___ #3___	#1___ #2___ #3___	#1___ #2___ #3___	#1___ #2___ #3___	#1___ #2___ #3___

2. Soil Moisture- The soil probe tester plates must be cleaned prior to use by rubbing with dull side of conditioning film. Soften soil in spot to be tested, break up pieces if it's hardened, and remove grass, leaves, pebbles and other debris. Insert soil tester so metal plates are fully covered and press the soil tightly around the tester so that the metal plates are in close contact with the soil. Press the button to read soil moisture content on the lower scale. Hold the button in the depressed position for 2 – 3 minutes or until value stabilizes. Record the reading obtained and repeat for a total of three measurements should be taken from each plot.

Plot 1 (5m RB)	Plot 2 (5m LB)	Plot 3 (50m RB)	Plot 4 (50m LB)	Plot 5 (95m RB)	Plot 6 (95m LB)
#1___ #2___ #3___	#1___ #2___ #3___	#1___ #2___ #3___	#1___ #2___ #3___	#1___ #2___ #3___	#1___ #2___ #3___

3. Plant cover and structural diversity- Within each 100m² sample plot estimate the percent cover (the shadow cast by a particular layer) of the canopy (cp), understory (us), and groundcover (gc) vegetation layers. The canopy layer is >5m high, the understory is 0.5 to 5m high, and the ground cover is <0.5m high (roughly knee height). Only consider vegetation within the sampling plot. The surveyors should walk the plot focusing on 1 vegetation category at a time and then agree on one value to record. Running a measuring tape to better define the study plot or dividing transect into smaller units can help to obtain a more accurate estimation.

Plot 1 (5m RB)	Plot 2 (5m LB)	Plot 3 (50m RB)	Plot 4 (50m LB)	Plot 5 (95m RB)	Plot 6 (95m LB)
cp___ us___ gc___	cp___ us___ gc___	cp___ us___ gc___	cp___ us___ gc___	cp___ us___ gc___	cp___ us___ gc___

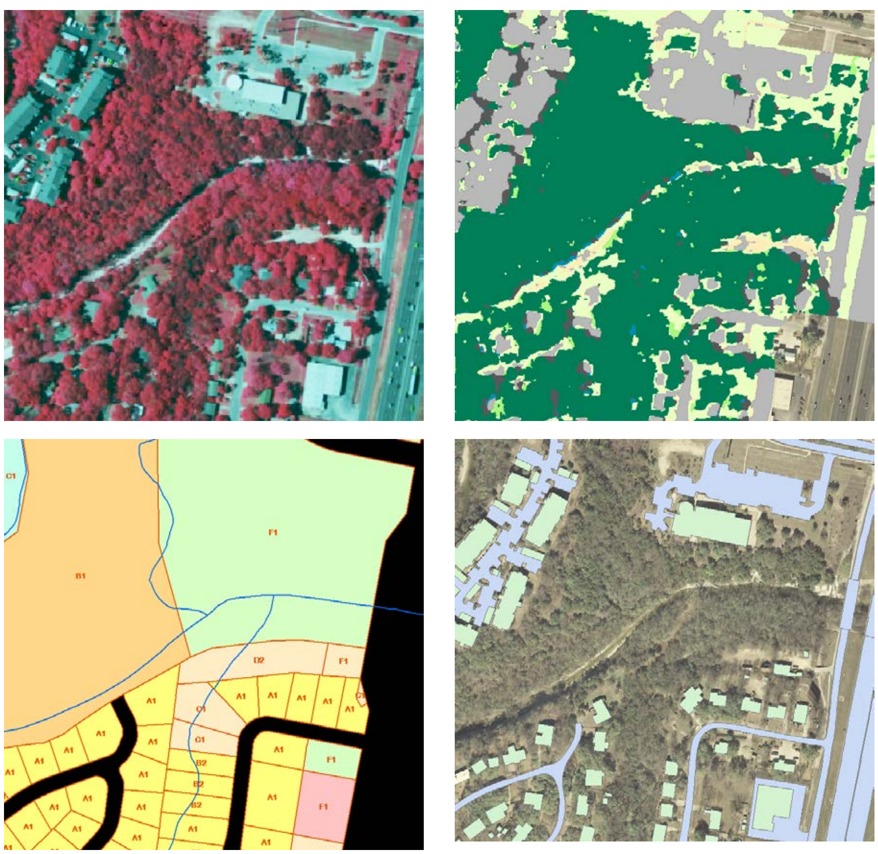
4. Woody Demography- Within each 100m² sampling record the dominant tree present (highest percent coverage of study plot. the shadow cast by a particular layer) and record the presence or absence of multiple age classes (seedlings, saplings, mature, and snags). Seedlings are defined as 12" or less having sprouted within the last year, saplings are > 12" in height but have yet to reach half its mature height and lack a full defined canopy, mature trees are approaching their maximum height and display a full developed canopy, and snags are dead trees with little to no vegetation and reduced canopy coverage often resulting from broken limbs.

Plot 1 (5m RB)	Plot 2 (5m LB)	plot 3 (50m RB)	Plot 4 (50m LB)	Plot 5 (95m RB)	Plot 6 (95m LB)
Species___	Species___	Species___	Species___	Species___	Species___
Classes present: seedling, immature, mature, snags	Classes present: seedling, immature, mature, snags	Classes present: seedling, immature, mature, snags	Classes present: seedling, immature, mature, snags	Classes present: seedling, immature, mature, snags	Classes present: seedling, immature, mature, snags

seasons, then active seeding, planting, or vegetation management may be necessary, especially if other variables such as compaction and moisture have improved.

Index of Riparian Integrity

Riparian zones along a stream have significant influence on the integrity of the adjacent aquatic ecosystem. Traditional field methods of assessing riparian zones in large stream networks may be prohibitively time consuming and expensive. Remote sensing can be used to characterize the riparian zone in aggregate and identify areas with a high potential of functional deficiency. The City of Austin has developed a GIS-based assessment tool to evaluate stream corridor integrity. Aerial vegetative classifications and land use data from two riparian buffer widths (50 feet and 400 feet) were combined in a multivariate spatial cross-regressive model to specify the overall riparian integrity of a watershed-scale reach. Accuracy checks showed the results to be mostly accurate with problems potentially arising when a watershed reach was composed of only the 640 acre drainage area or total impervious cover percentages were drastically different between the 50 foot and 400 foot buffer where the land use was primarily commercial. The results of the model produced the Index of Riparian Integrity, which can be considered by project managers in prioritizing riparian restoration.



Examples of color infrared photography, a classified image, land use, and planimetric data for impervious cover.

Field Operations

The City's stormwater conveyance system is composed of natural and engineered creeks and channels, a network of drainage pipelines, and structural stormwater management controls. The Field Operations Division (FOD) is responsible for the maintenance of this system, which includes a variety of activities to ensure conveyance for stormwater runoff. FOD staff remove excessive vegetation, debris, and obstructions from open channels and waterways, culverts, and bridge locations. The Open Waterways Maintenance (OWM) program provides removal of accumulated sediments, debris, trees, brush, and other obstructions to stormwater flow from creek beds to increase capacity. This program involves more rugged work, requiring heavy equipment and skilled City staff in response to storm clean-up needs and citizen complaints.

Routine vegetation control is achieved primarily through private sector maintenance contracts. The purpose of Vegetation Control Program (VCP) is to remove excessive vegetation, trash, and debris from creeks to reduce flood hazards and property flooding potential. The core services of the program include contract management and oversight of the contract with the Texas Industries for the Blind and Handicapped, in conjunction with the Capital Area Easter Seals Organization. Core services also include citizen complaint investigation and resolution, coordination of vegetation and debris removal on flood and erosion control buyout properties, and coordination with internal and external customers related to native plant restoration efforts along segments of creeks and waterways through the City.

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Degradation of riparian zones from excessive mowing, invasion of non-native species, and a lack of diversity of plants can result in less infiltration of runoff, less uptake of water pollutants and excessive loss of land by erosion. Biologists and engineers collaborated with Field Operations to shift more than 6.75 acres of riparian zones to less intensive maintenance thereby reducing maintenance costs for WPD operations and improving stream conditions. Additional sites will be evaluated through modeling to determine whether a higher roughness coefficient from reduced mowing would lead to flooding of adjacent structures.

In addition to evaluating individual sites, Field Operations also worked with staff biologists and engineers to revise the Vegetation Control Program contract to include specific maintenance regimes for different tiers of streams (e.g., no mowing allowed, mow to 12”, mow to 6”). Staff also revised Section 10-5-21 of the City Code to allow grasses more than 12” tall in an area within or adjacent to a stream, waterway, or water quality facility. This revision allows both the City, as well as private citizens, to maintain healthy vegetation in riparian zones without being cited by the Code Compliance Department.

6.4 Case Studies

Willowbrook Restoration

Residential development along the stretch of Boggy Creek known as the Willowbrook Reach began in the late 1940s. Earlier depletion of native vegetation from domestic animal grazing followed by residential development and associated urban influences have led to the relatively poor condition of this stream today. After staff evaluated a decrease in rate of erosion in 2010, it was determined that structural restoration was unnecessary. Instead, an effort was undertaken to improve riparian zone structure and function in this reach by adding groundcover, understory, and canopy vegetation to the existing riparian community with input and involvement of local stakeholders. With an approach developed by the Watershed Protection Department, a trail and stream crossing were installed and 1.6 acres of riparian land was planted with native trees, shrubs and groundcover. A cost comparison shows that riparian restoration, at about $50 per linear foot, has the potential to cost far less than traditional bank and channel stabilization, at about $850 per linear foot.

A full range of riparian measures were not taken prior to the initiation of this work. An inventory of non-native invasive plants and estimated coverage should be compiled along with types of historic disturbance. This information can then be used to better identify and customize further restoration efforts. When intensive mowing has occurred for a long time and the location is deplete of native species there will be a greater need for seed dispersal to compensate for lack of seed source. If an area that has been allowed to revegetate itself and is replete with both native and non-native plants, a greater benefit might come from just managing the non-natives. In addition to tree and

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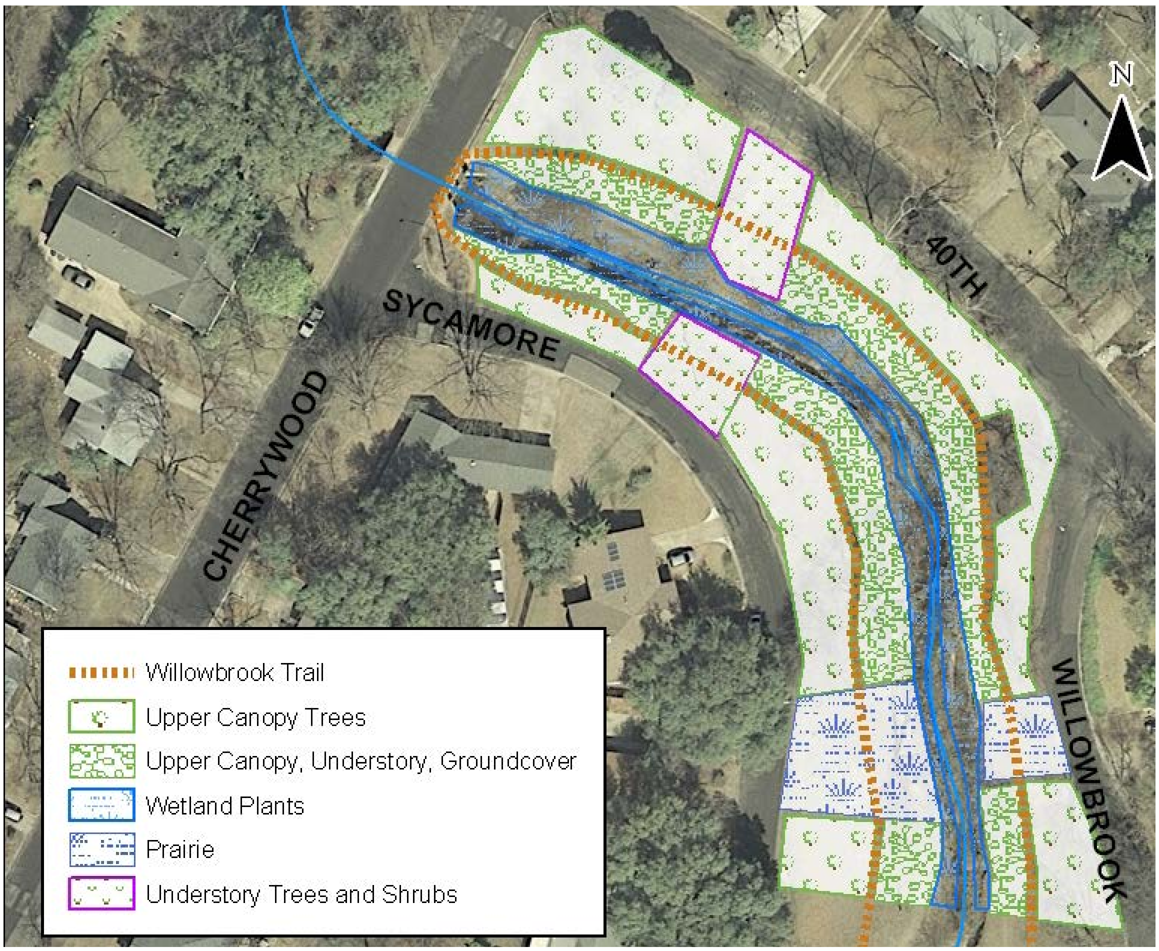
shrub seeds, more aquatic plants and bare root grasses should be planted. Future restoration sites should receive more rooted plants in and at the water's edge, where water quality and erosion benefits are direct and possibly more effective.

The Willowbrook restoration effort provides a good example of base costs and effort for riparian revegetation in urban Austin. It appears to be a relatively affordable approach when compared to more structural stream restoration efforts, provided those efforts are not required due to flood or erosion constraints. There are times when property and safety are at risk and the engineered approach is necessary, but in many situations riparian restoration, like the work done at Willowbrook, is an efficient model to utilize.



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7 Sewage

7.1 Problem Score Calculation

Sewage = 100 – average [bacteria EII and min (nutrient or % algae EII)]

This score prioritizes stream reaches with high bacteria and high nutrient or algae growth which are most likely impaired by leaking wastewater infrastructure. Damage due to root penetration, corrosion, exposure of wastewater lines in creek channels from bank erosion and aging may lead to release of raw sewage from the collection system. Defective wastewater infrastructure also allows for infiltration of rainwater into the collection system potentially compromising treatment plant operations or leading to sanitary sewer overflows (SSO). In addition, wastewater disposal by either Texas Land Application Permit (TLAP) and by individual on-site sewage facility (OSSF) may pose a threat to water quality and public safety as non-point sources of pollution if failing or improperly managed. There may also be some cumulative water quality impacts from OSSF and TLAP facilities currently operating within permitted or design limits.

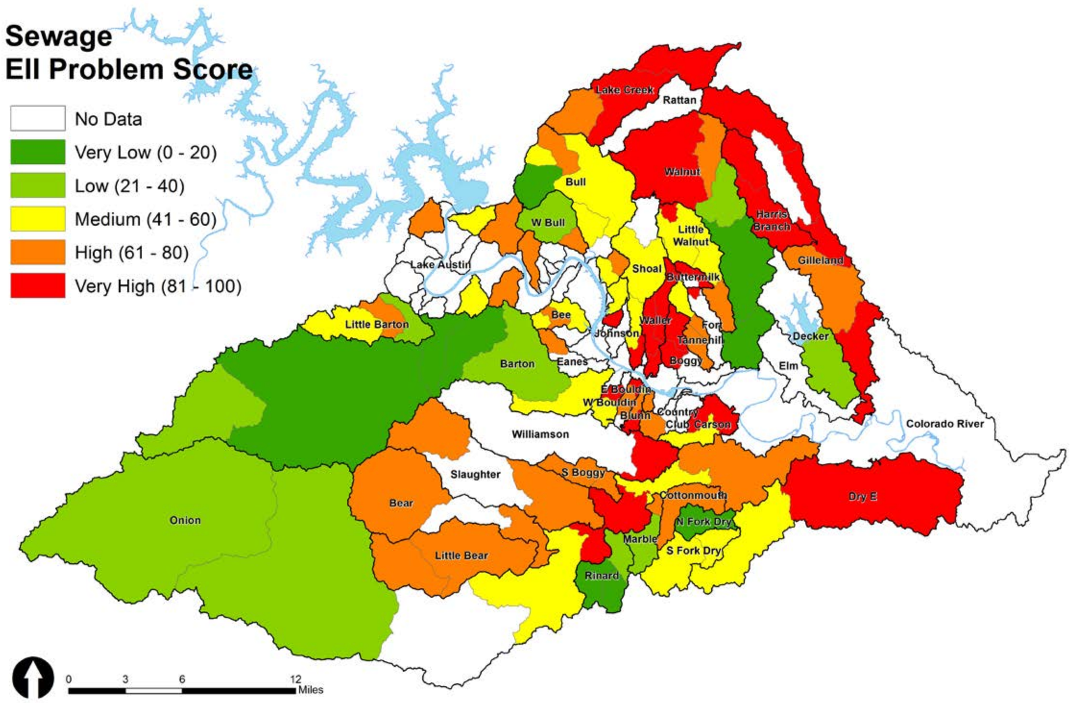
The ecological effects of raw wastewater on streams has been studied for over a hundred years, primarily targeting direct discharges to larger receiving waters and leading to the Clean Water Act. However, spatial and temporal effects from small pulse and chronic leakage events on ecosystem structure and function in smaller streams has not been well documented. The result of these types of events has recently been included in what has been coined the "urban stream syndrome," which brings together the wide range of stressors that dense development brings to stream systems.

A Watershed Protection Department study of wastewater spills showed that ecological response including macroinvertebrates and diatom communities was dramatic both spatially and temporally. Recovery to background conditions only occurred at one of the study streams after two months of monitoring and degradation of benthic macroinvertebrate communities observed at extended distances downstream of the spill location. Discrete functional changes in the macroinvertebrate community were consistent among study streams. The duration of the wastewater release event, which varied among the study streams, appears to be more important than the magnitude of the spill in determining stream impacts. Results from this study suggest that sewage overflows are a significant stressor in urban streams, causing more severe and longer term ecological degradation than was previously thought.

7.2 Base Map

The Base Map is an ArcGIS document that organizes and displays data related to sewage, including both potential sources (e.g., wastewater lines, OSSFs) and potential solutions (e.g., lines removed by the ACWP program). The purpose of the Base Map is not only to provide a clearinghouse of related data, but also to allow staff to spatially correlate potential sources and solutions with the problem scores for individual EII reaches.

This data was identified through meetings with internal department stakeholders and is a combination of existing GIS data as well as newly-created GIS data. Upon completion, the Base Map was reviewed by the internal stakeholders and additional updates were completed.



7.3 Actions

Introduction

The Watershed Protection Department addresses water quality degradation associated with sewage using a three-tiered approach of programs, regulations, and capital improvement projects.

Examples of programmatic solutions include spills response (see Sanitary Sewer Overflows) and ongoing monitoring (see Urban Creek TMDLs). Examples of regulatory solutions include standards and requirements for placement of wastewater infrastructure (see Regulatory Requirements) as well as the implementation plan for TMDLs in Urban Creeks. Examples of capital improvement projects include the multiple projects implemented by the Austin Clean Water Program to remove wastewater infrastructure from creeks.

Sanitary Sewer Overflows (SSO)

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Sanitary sewer overflows (SSO) occur when equipment failures, blockages, breaking, or inflow and infiltration of rainwater or groundwater that overwhelms the capacity of wastewater lines, cause a release of sewage from the wastewater collection system. Fecal contamination of receiving waters from SSO may contribute to fecal bacteria levels in excess of contact recreation standards.

Austin Water personnel are on duty or on call 24 hours a day, 7 days a week, to respond to SSO. The objective of the Austin Water response program is to arrive at the source of the wastewater emergency within one hour of receiving the call and control the overflow as soon as possible by starting wastewater bypass pumping systems, locating and eliminating the cause of the interrupted wastewater service, and recovering or disinfecting spilled wastewater as soon as possible. Austin Water personnel have equipment and staff to control most wastewater emergencies, but may also utilize private contractors for pumping and hauling wastewater as needed.

The Austin Water personnel and private contractors perform closed-circuit television inspection and cleaning of the wastewater collection system piping. The program is part of a preventative maintenance effort to minimize sanitary sewer overflows by repairing or replacing defective piping that may impact water quality or wastewater system reliability. Defects that are observed in the wastewater piping are recorded in a database and prioritized for repair. Inspection is conducted on approximately 2.5 million feet of wastewater lines per year citywide, representing approximately 12.5% of the total system length. Rehabilitation projects are conducted on approximately 40,000 to 50,000 feet of wastewater lines per year citywide to prevent SSO and infiltration and inflow of rainwater. Rehabilitation projects are prioritized based on overall condition and criticality of the line. Expanded maintenance activities or increase in the frequency of inspection of the collection system could be accomplished with increased funding.

The Watershed Protection Department receives notification from the Austin Water of all SSO events. Watershed Protection Department staff investigates any SSO greater than 50 gallons, as well as any SSO which may affect a storm sewer or water body, to ensure impacts to receiving waters are minimized. The Watershed Protection Department also directly investigates citizen complaints of polluting discharges, and report to the Austin Water if illicit sanitary sewer connections to the storm drain system are detected or if SSO are observed. The City of Austin uses the 3-1-1 call system and the 24-hour 512-974-2550 environmental hotline to provide for citizen reporting of SSO. In addition, the City uses public education efforts to reduce the likelihood of SSO with educational campaigns like the Ban the Blob initiative to reduce disposal of grease into the sanitary sewers.

Austin Clean Water Program

On April 29, 1999, the City of Austin and the U.S. Environmental Protection Agency (EPA) signed an agreed order for remedy of violations under the Clean Water Act (CWA) related to sanitary sewer overflows. Specifically, the AO indicated that at "relevant times, each facility [wastewater and collection facility] …was a 'point source' or a 'discharge' of 'pollutants' with municipal wastewater to various 'waters of the United States' in Segment 1428 of the Colorado River Basin…." This was a violation of the National Pollutant Discharge Elimination System (NPDES) program. The Order stipulates actions to be taken in order to assess the wastewater collection system and prevent future overflows with milestones and a final compliance date of December 31, 2007.

The City began the Austin Clean Water Program to fix the sanitary sewer system and to reduce sewage overflows that were affecting creeks and waterways. The City faced heavy fines from the Environmental Protection Agency (EPA) if it did not complete the project by June of 2009. However, the program was completed by the spring of 2009, ahead of schedule, and EPA ended its enforcement action.

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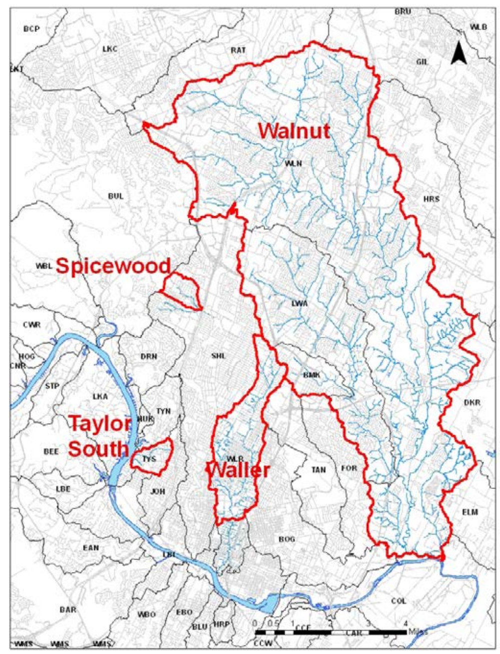
The $400 million program involved 100 separate projects in 70 neighborhoods. This included replacing or repairing nearly 200 miles of pipe; eliminating 10 sewage lift stations; rerouting miles of sewer pipes away from streams; restoring stream banks; and improving response time to calls about sewer emergencies. As a result of this program, there has been a dramatic drop in the volume and number of sewage overflows. In fact, recent testing shows that water quality has improved in at least a dozen of Austin's creeks.

The program was voted one of the top 10 infrastructure projects in North America in the last 75 years by The International Right of Way Association. The selection was based on projects that have had the "greatest impact on the American quality of life."

TMDLs in Urban Creeks

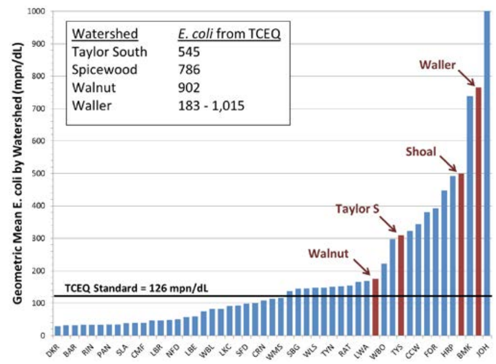
The Texas Commission on Environmental Quality (TCEQ) is required to regularly identify water bodies in Texas that do not support their designated uses. Human contact recreation impairment due to elevated levels of fecal indicator bacteria is the most common water quality impairment in Texas. Watershed Protection Department monitoring has identified a range of watersheds in Austin that have levels of fecal indicator bacteria above State of Texas long-term standards. Fecal indicator bacteria are used to measure the long-term potential for fecal contamination, and are not a direct representation of the risk to humans from water contact.



WPD has conducted water quality monitoring in 50 Austin watersheds since 1996. Seven of these watersheds have ended up on the TCEQ list of impaired water bodies due to elevated bacteria levels. The combined actions of WPD, the Austin Water (AW) and regional partners have removed 3 watersheds from the TCEQ draft 2012 list of contact recreation impairments. In March 2012, the Directors of AW and WPD determined that pursuing a Total Maximum Daily Load (TMDL) in cooperation with TCEQ for the remaining 4 watersheds on the TCEQ list (Walnut, Taylor Slough South, Spicewood Tributary to Shoal Creek, and Waller Creek) was the most appropriate action for the City of Austin.

A TMDL is a determination made by the TCEQ of the quantity that fecal bacteria must be reduced for a watershed to no longer be impaired. An Implementation Plan is a separate document that identifies the activities that will be conducted by stakeholders in the watershed that will achieve the necessary reductions of bacteria. TCEQ staff are developing a TMDL for the 4 watersheds. The Implementation Plan is being developed simultaneously by a Coordinating Committee composed of City of Austin staff and the public, facilitated and organized by the University of Texas Law School as a paid contractor for the TCEQ.

As the primary departments responsible for implementing fecal bacteria reduction actions in streams, staff from AW and WPD are participating as members of the Coordinating Committee. AW and WPD staff will be responsible for relaying information back to other City of Austin groups and will involve other departments as necessary through work groups. The City of Austin is in control of all commitments made in the Implementation Plan, and all proposed actions are voluntary. Because the City of Austin recognizes this as a citywide issue, the proposed actions to reduce fecal pollution will be implemented on a Citywide basis as much as is feasible, even though the TCEQ-mediated process will focus only on these four watersheds.



In addition, a bacteria source identification project is being designed to identify the source of the fecal contamination to more efficiently direct remediation with the goal of removing the impairments. More information on this project is available in the Bacteria from Animals Watershed Plan.

Regulatory Requirements

The Texas Commission on Environmental Quality (TCEQ) regulates wastewater discharges to waterways and wastewater effluent land application. The TCEQ currently uses methods that do not completely characterize the impacts of wastewater discharges on receiving waters and thus issues permits that do not adequately protect water quality, particularly with respect to nutrient enrichment of high quality streams and reservoirs. Wastewater discharges are prohibited in the Recharge Zone of the Edwards Aquifer but not in the Contributing Zone. Although wastewater discharges are prohibited by rule within 10 stream miles of the Highland Lakes, discharges are allowed outside of that water quality management area and modeling has shown that these discharges can affect the quality of these regionally important recreational and water supply reservoirs (see the City of Burnet Case Study). Additionally, on-going research by the City of Austin indicates that the current permit limitation for land application of wastewater effluent under the Texas Land Application Permit (TLAP) system may not meet the stated goals of no water quality impacts.

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Wastewater regulations are found in multiple sections of Title 30 of the Texas Administrative Code, Part 1 (TCEQ). Some of the relevant sections and their potential policy implications are listed below:

- Chapter 213, Edwards Aquifer.

  This chapter recognizes the significance of the Edwards Aquifer and contains limitations on wastewater discharges in the Contributing Zone and prohibition on discharges in the Recharge Zone.

- Chapter 307, Texas Surface Water Quality Standards (anti-degradation) 307.5(b)(2) "Degradation is defined as a lowering of water quality by more than a de minimis extent, but not to the extent that an existing use is impaired."

  There is no published quantitative method in TCEQ guidance for determining de minimis water quality degradation.

- Chapter 311(A), Watershed Protection.

  This chapter recognizes the resource value of the Highland Lakes and contains the provisions regulating wastewater discharges in the Highland Lake watershed area.

- Chapter 309 and Chapter 222.

  These chapters contain regulations for land application of sewage effluent and additional criteria and effluent sets for direct wastewater discharges.

The City of Austin Water regulates on-site sewage facilities (OSSF) generating less than 5,000 gallons of wastewater per day. The City of Austin is an Authorized Agent of the Texas Commission on Environmental Quality (TCEQ), and the Austin Water is a Designated Representative to administer the program. The program falls primarily under the authority of TCEQ rules contained within 30 TAC Ch. 285, On-Site Sewage Facilities. The Austin Water waives wastewater capital recovery fees (approximately $2,000 per connection) after full purpose annexation as an incentive to abandon existing OSSFs and connect to the City of Austin-owned centralized wastewater collection system as new wastewater mains become available in recently annexed areas.

In addition to state law, the City of Austin Land Development Code prohibits wastewater treatment by land application on slopes with a gradient of more than 15%; in a critical water quality zone; in a 100-year floodplain; or during wet weather conditions. The Watershed Protection Ordinance proposes to add prohibitions for critical environmental features as well. The City of Austin is currently working on a revision to the OSSF Ordinance with additional provisions for sizing, design, and maintenance, including enhanced protection for the recharge zone and Lake Austin.

In addition to these ordinance revisions, potential modifications to improve the existing wastewater discharge permit process could include:

- Continuing to support the prohibition on wastewater discharges in the Recharge Zone of the Edwards Aquifer and within 10 miles of the Highland Lakes. The City of Austin successfully protested a petition by two cities to allow wastewater discharges to the Highland Lakes

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in 2010. With overwhelming support for the existing prohibition, the Texas Commission on Environmental Quality denied the petition and the discharge ban remains in effect.

- Pursuing discharge and TLAP rule changes or TCEQ agency practices sufficient to routinely protect water quality.
- Protesting and negotiating any individual permit action that does not adequately protect water quality in high resource value watersheds.
- Accruing relevant national research and pursue monitoring and modeling projects in the Austin area to fill critical data gaps to not only establish a scientific basis to support City of Austin policy decisions but also to provide a body of evidence to TCEQ in support of rule revisions.

The implementation of these potential modifications would include the following actions:

- Participate in routine TCEQ technical advisory and topical stakeholder processes as they occur regarding TCEQ surface water quality standards, Edwards Rule Revisions, and other relevant groups to share results of current research and guide processes towards more effective water quality protection.
- Work with regional partners (LCRA, Barton Springs/Edwards Aquifer Conservation District, Texas Parks and Wildlife Department, Travis County, Hays County, Dripping Springs, and citizen groups) to petition for rule changes, support legislative reforms, and coordinate on research efforts, education and outreach.
- Provide elaborate and timely comments on any individual wastewater permits with the potential for adverse water quality impacts; protest or negotiate permits that would impact water resources Citywide. See case study on City of Burnet Wastewater Discharge.
- Pursue literature research, water quality monitoring and dynamic modeling to predict and document water quality impacts before and after wastewater degradation to guide scientifically-based policy decisions at COA and TCEQ.
- Work with the Barton Springs Zone Regional Water Quality Protection Plan stakeholders to develop consensus recommendations for appropriate wastewater management that is protective of surface water and groundwater resources and pursue necessary municipal, county and state rule revisions necessary to implement those recommendations.

7.4 Case Studies

City of Burnet Wastewater Discharge

The City of Burnet applied to the TCEQ to increase the amount of treated wastewater they could discharge into a creek that flows into the upper end of Lake Travis. Wastewater discharges are regulated by TCEQ, and the City of Austin has limited opportunities to modify the permits to make them more protective of water quality. Although TCEQ prohibits wastewater discharges within 10 stream miles of Lake Travis, Burnet is outside of the prohibited area. Water quality modeling performed by Watershed Protection Department staff predicted that Burnet's original request

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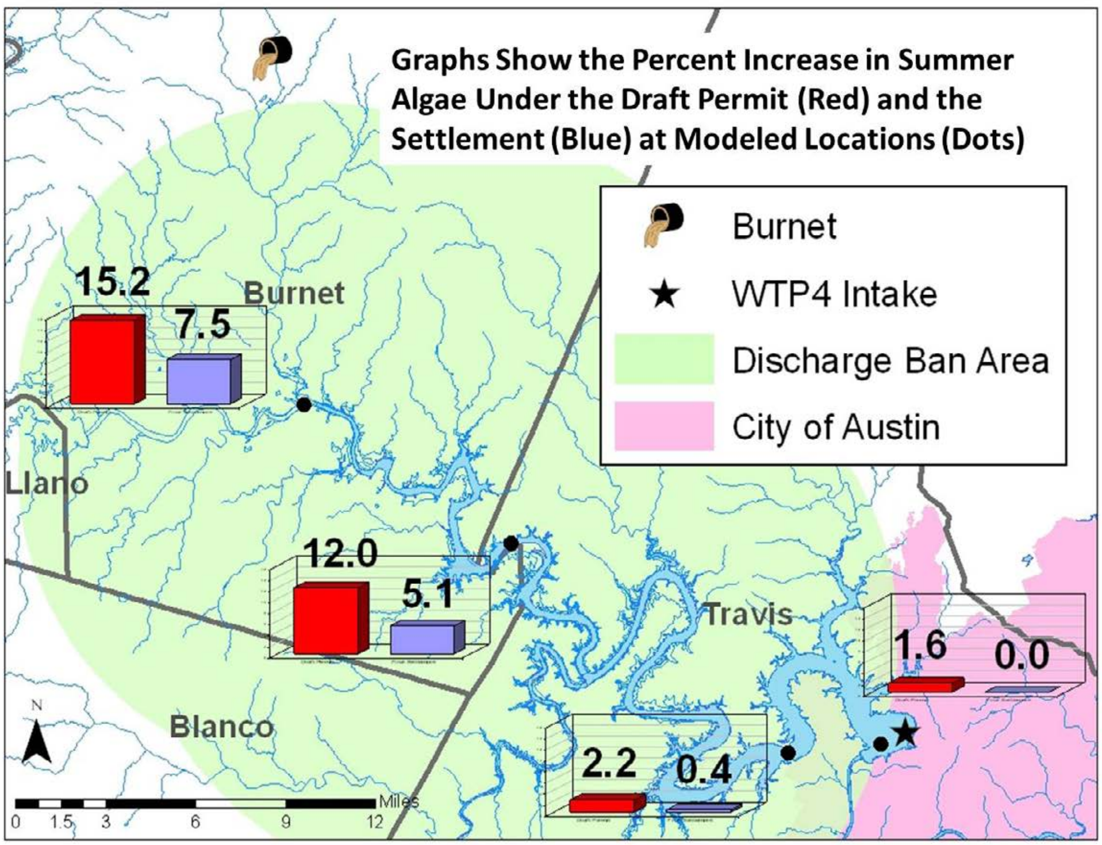
would increase summer algae in the upper end of Lake Travis, and it would measurably affect the lake downstream to the new raw water intake for the City's new water treatment plant. The City of Austin and the LCRA worked with the City of Burnet to reach a settlement that was more protective of water quality. Under the terms of the settlement agreement, the level of wastewater treatment required of Burnet was significantly improved. The settlement reduces by half the predicted impact of discharges on summer algae growth in the upper end of the lake and eliminates any impact in the downstream basin where the new water treatment plant intake is located.

Read more about the potential effects of the City of Burnet's wastewater discharge on Lake Travis at http://assets.austintexas.gov/watershed/publications/files/SR-10-04_Burnet_WW_Discharge.pdf.



Predicted increase in summer algae in Lake Travis from the City of Burnet's wastewater discharge as originally proposed by Burnet (red) and as improved by the settlement agreement with the City of Austin and LCRA (blue).

7.5 Supporting Documentation

Texas Surface Water Quality Standards, which establish the type and criteria for indicator bacteria to support designated or assumed contact recreation uses of water bodies: http://info.sos.state.tx.us/pls/pub/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=307&rl=Y

TCEQ Implementation Manual, describing procedures by which bacteria data should be assessed: http://www.tceq.texas.gov/assets/public/compliance/monops/water/10twqi/2010_guidance.pdf

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TCEQ 303(d) list: http://www.tceq.texas.gov/waterquality/assessment

TCEQ Recreational Use-Attainability Analyses (RUAAs) Procedures: http://www.tceq.state.tx.us/assets/public/waterquality/standards/ruaa/Recreational%20UAA%20Procedures_Final_2012.pdf

On-going EPA research activities: http://water.epa.gov/scitech/swguidance/standards/criteria/health/recreation/index.cfm

Contact recreation guidelines in Town Lake: http://www.cityofaustin.org/watershed/downloads/townlake_rec.pdf

Herrington, C. 2011. Summary of 303(d)/305(b) Listed Segments from the Draft 2010 Integrated Report in the Austin area, Texas (DRAFT). City of Austin, Watershed Protection Department, Environmental Resource Management. SR-11-11.

Herrington, C., and T. Jackson. 2012. Supplemental monitoring of selected water bodies with contact recreation impairments. City of Austin, Watershed Protection Department, Environmental Resource Management. SR-11-04.

Herrington, C., and M. Scoggins. 2006. Potential Impacts of Hays County WCID No. 1 Proposed Wastewater Discharge on the Algae Communities of Bear Creek and Barton Springs. City of Austin Watershed Protection and Development Review Department. SR-06-08.

Herrington, C. 2005. Potential Effects of On-Site Sewage Treatment Facilities on Surface and Groundwater Quality in Travis County, Texas. City of Austin Watershed Protection and Development Review Department. SR-05-04.

8 Toxins in Sediment

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8.1 Problem Score Calculation

Toxins in Sediment = 100 – min (PAH, pesticide or metal EII)

This score prioritizes sites with the worst (most toxic) concentrations of polycyclic aromatic hydrocarbons (PAHs), pesticides, or metals in sediment. Sediment data are collected from the mouth of each EII-monitored watershed and sediment scores are derived from toxicity estimates of the sediment constituents. PAHs come from coal-tar based pavement sealants, combustion of organic matter, and petrochemicals. Pesticides are generally from landscape maintenance in urban areas, although some highly persistent banned pesticides are still detected from historic use. Metals originate from a variety of sources, including automobiles. Industrial areas may be "hot spots" for certain metals, depending on the type of process and management of materials.

Sediments are an integral part of the benthic environment, providing feeding, habitat, and rearing areas for many aquatic organisms. Many non-point source pollution related contaminants are hydrophobic and will adsorb to the sediments, settle in the creek bed, and accumulate at elevated levels in the benthic environment. Sediments serve as both a short-term sink and a long-term source for contaminants in the aquatic environment. They can release accumulated contaminants to the water column and biota very slowly or very quickly due to natural or artificial disturbances. While release stimulated by bacterial decomposition and solubilization can be slow in undisturbed conditions, rapid release and relatively high concentrations in the water column have been correlated to localized organic matter decomposition concentrating low-flow conditions and stormwater flushes.

Sediment-sorbed contaminants have been associated with a wide range of impacts on the plants and animals that live within and upon bed sediments. Chronic and, in some cases, acute toxicities of sediment-sorbed contaminants to algae, invertebrates, fish, and other organisms have been measured in laboratory toxicity tests. Human health effects have also been associated with sediment-sorbed contaminants, prompting development of health-based water quality criteria. The most direct route to humans is often consumption of fish tissue that has had the time to bioaccumulate various organic contaminants or metals.

8.2 Base Map

The Base Map is an ArcGIS document that organizes and displays data related to toxins in sediment, including both potential sources (e.g., underground storage tanks, coal-tar sealed parking lots) and potential solutions (e.g., structural controls, SDPP inspection). The purpose of the Base Map is not only to provide a clearinghouse of related data, but also to allow staff to spatially correlate potential sources and solutions with the problem scores for individual EII reaches.

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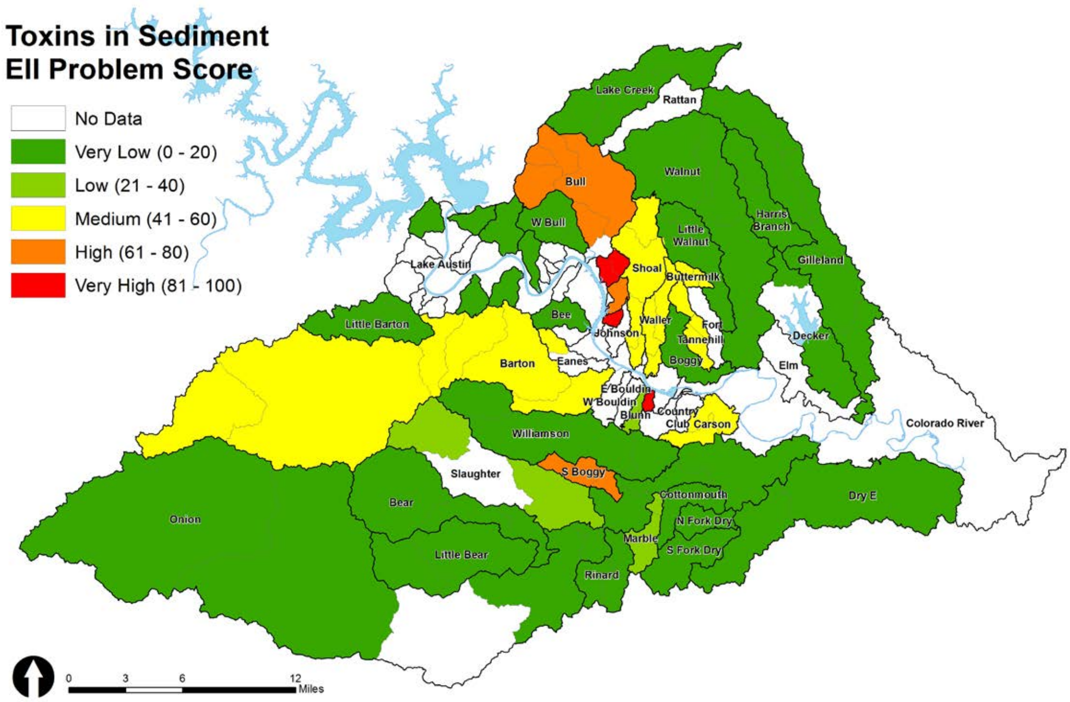
This data was identified through meetings with internal department stakeholders and is a combination of existing GIS data as well as newly-created GIS data. Upon completion, the Base Map was reviewed by the internal stakeholders and additional updates were completed.

8.3 Actions



Introduction

The Watershed Protection Department addresses water quality degradation associated with toxins in sediment using a three-tiered approach of programs, regulations, and capital improvement projects.

Examples of programmatic solutions include spills response, public education (see Pollution Prevention), and good housekeeping practices (see Stormwater Discharge Permitting Program). Examples of regulatory solutions include a ban on coal-tar based sealants, requirements for structural stormwater controls, and requirements for integrated pest management (IPM) plans. Examples of capital improvement projects include the remediation of sites contaminated by illegal dumping (see Rosewood Remediation Case Study).

Coal-Tar Sealant Ban

Research conducted by the U.S. Geological Survey (USGS) has identified coal-tar based pavement sealant as a significant anthropogenic source of PAH. Pavement sealant is a coal-tar or asphalt based

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black liquid sprayed on asphalt pavements, primarily parking lots. Once dry, the sealant binds to the surface layer and slows wear and degradation of the asphalt to prolong its useful life. Coal-tar-based sealants contain about 20 to 35% coal-tar pitch which is 50% or more PAH by weight and a known human carcinogen.

The City of Austin, in cooperation with the USGS, conducted several studies from 2000 to 2005 that examined concentrations and sources of PAH in creeks and lakes in Austin. The City found that not only was coal-tar sealant from parking lot run-off a source of contamination to the Austin waterways, but the PAH levels in some of the creeks were detrimental to aquatic life. Based on this information, the City of Austin enacted a ban on the use and sale of coal-tar based pavement sealant in 2006 within the City's planning jurisdiction, becoming the first community in the country to institute a ban. Since then, numerous communities, including the District of Columbia, Madison, Wisconsin, and the state of Washington, have enacted similar bans.

Sediment samples were collected in approximately 50 of Austin's largest watersheds from 1996 until 2010 and analyzed to evaluate the effect of the ban. While previous studies have shown that runoff from parking lots sealed with coal-tar sealant could contaminate the sediment of nearby creeks, it appears now that the majority of sites sampled for the Environmental Integrity Index were not contaminated to levels above the Probable Effect Concentration. The ban of coal-tar sealant should help minimize one of the larger PAH sources and prevent PAH concentrations from increasing.

One site that should be noted is Barton Creek above Barton Springs Pool. This site is immediately upstream of Barton Springs, which is occupied by the endangered Barton Springs Salamander and a recreational mecca for Austin citizens. Thus it is important for PAH levels to remain at a level that will not affect human or salamander health near this location. In the past, concentration of PAH has been above the PEC at this location; however, around the time period when the coal-tar sealant ban was implemented and a structural water control to capture stormwater runoff from a coal-tar sealed parking lot up gradient of the site was constructed, concentrations decreased to below the PEC at this site and have remained below the PEC. The combination of structural and regulatory best management practices appears to have reduced the PAH sources to Barton Creek, allowing concentrations in the creek to return to urban background levels.

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Pollution Prevention

Stormwater Discharge Permitting Program

The Stormwater Discharge Permit Program staff conduct inspections of specific commercial and industrial operations within the City of Austin limits to ensure compliance with City Codes which protect water quality. Inspectors locate, verify, and monitor plumbing connections to the City storm sewer system and receiving waterways to prevent illegal discharges of commercial or industrial wastes. Inspectors check waste storage, handling and disposal practices as well as premise maintenance activities to prevent illegal discharges. A Stormwater Discharge Permit is issued to the facility on an annual basis. Each facility is responsible for obtaining and maintaining a current permit. Legal action is taken against Code violators when necessary. Inspectors notify and coordinate efforts with other related agencies.

Other program activities include:

- Reviewing proposed and existing non-stormwater discharges to the storm sewer system or waterways from activities such as swimming pool filter backwashing, construction work, cooling tower blowdown, and secondary tank containment releases.
- Responding to requests for inspections owing to property assessments, remediations, proposed temporary discharges, or a change in property ownership or management.
- Tracking and dye-tracing plumbing connections to the storm sewer system to determine the route of materials through the system.
- Collecting samples for analysis, typically for enforcement purposes.
- Providing guidance to the responsible parties during remediations.
- Recommending Best Management Practices (BMPs) applicable to each facility or operation. These are pollution prevention measures geared to reducing pollutants at the source and preventing the release of potential pollutants with stormwater.
- Providing education materials, such as lists informing operators how to dispose of or recycle waste materials.

Several types of industrial and commercial activities are currently inspected and permitted under this program. Included in the list below are some of the regulated operations and the typical wastes that each generates. These wastes must be disposed of properly, not on the ground or to a storm drain or waterway.

- Motor Rebuilding and Repair—oil, caustic cleaner sludge, oven residues, solvents, degreasers, used absorbent materials
- Machine Shop Services—blast abrasives waste, caustic cleaner sludge, oven residues, solvents, degreasers, used absorbent materials
- Transmission Rebuilding and Repair—oil, transmission fluid, solvents, caustic cleaner

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sludge, oven residues, degreasers, used absorbent materials

- Radiator Repair—antifreeze, leak test tank wastewater and sludge, boil-out tank sludge, paint, solder, soaps and detergents, used absorbent materials
- Fuel Storage and Dispensing Facilities—gasoline, soaps and detergents, used absorbent materials
- General Auto, Truck, Aircraft, Boat, and Equipment Repair—oil, grease/lubricant, antifreeze, batteries, used auto parts and scrap metal, brake fluid, carburetor cleaner, oil filters, fuels, solvents, power steering fluid, empty containers, shop rags, used absorbent materials, transmission fluid, tires, general shop trash, oil/grit separator sludge
- Readymix Concrete Companies—gravel, sand, concrete dispersing agents, concrete hardening compounds, vehicle washing materials (acids, rust inhibitors, detergents), diesel fuel, lubricants
- Chemical Manufacturing and Storage—could include any type of chemical
- Auto Salvage—waste oil, used batteries, fuel, antifreeze, scrap metal and used auto parts, oil filters
- Mobile Pressure Washers—cleaning agents, oil and grease, sediment
- Mobile Carpet Cleaners—cleaning agents, oil and grease, dirt and residue
- Auto Detailers—cleaning agents, oil and grease, sediment

Public Education

The Austin Clean Water Partners (ACWP) Program is a cooperative effort between the City of Austin Watershed Protection Department and local businesses. Businesses are encouraged to adopt shop practices that keep pollutants from entering storm drains and waterways. Those who participate are provided with rewards that benefit both the shop operators and their customers.

The Shade Tree Mechanic Program seeks to assist Austin's "at home" mechanics by providing them with the tools and information to help protect the environment while doing vehicle repair. Information is provided on proper product and waste storage and handling, waste recycling and

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disposal, and spill prevention and cleanup measures. A free reusable oil change pan, filter screen, and transport container is provided. Usage instructions and recycling information is printed on each container.

Street Sweeping

The Austin Resource Recovery Street Cleaning Program targets the cleaning of curbed City streets in all areas within the City limits for removal of sediment and debris which has collected in the streets and gutters, for health, safety, aesthetic and water quality reasons. The collected sediment may potentially contain PAHs and heavy metals associated with automotive use (e.g., brake and tire wear).

Household Hazardous Waste Facility

The City's Austin Resource Recovery is responsible for the development and management of the City's Household Hazardous Waste (HHW) Program. The City of Austin's HHW Program serves the residents Austin and Travis County, Texas. The program focus is on decreasing pollution from indiscriminate use or disposal of home chemicals and used oil, thus preventing pollution of local watersheds contributing to the Colorado River. The City's HHW has serviced over 130,000 households and collected over eleven (11) million pounds of household hazardous waste for recycling or proper disposal since the program's inception in 1986. Not only has this program safely diverted hazardous waste from improper dumping, the landfill, and wastewater systems, it also substantially increases the safety of solid waste workers who may be exposed to such chemicals during garbage collection or at the landfill.

Spills Response

This program seeks to protect the water quality of streams and related natural resources in Austin. This program targets illegal or illicit discharge to the storm sewer system and spills of hazardous and non-hazardous materials, which might be a threat to water quality within the City's planning jurisdiction and water supply watersheds. Discharges may occur through illicit plumbing connections to the City's storm sewer system, deliberate dumping, or accidental spills of hazardous and non-hazardous materials.

The responsibility for responding to surface water quality complaints and hazardous and non-hazardous materials spills for water quality protection is held by the Environmental Resource Management Division, Pollution Prevention and Reduction Section as a part of the Watershed Protection Department. The Austin Fire Department (AFD) is responsible for responding to hazardous material spills for protection of human health and safety. AFD also responds to certain non-hazardous materials releases that may be a threat to life, property, or the environment. The TCEQ is responsible

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for regulating disposal of hazardous waste, dealing with pollution threats to groundwater and protecting surface water for the State of Texas, which includes the City of Austin.

WPD maintains a rapid response capability by having investigators on-call on a rotating basis, and after-hours notification of environmental emergencies is accomplished through a 24-hour hotline operated by WPD. In a typical response situation, the Spills and Complaints Response Program (SCRP) investigators are notified of hazardous material incidents by the AFD dispatch office. Occasionally, this notification is from the TCEQ or the Austin and Travis/Travis County Health and Human Services (HHSD). Water pollution complaints are received from many sources: directly from private citizens calling the department's Pollution Hotline, from referrals from other City departments such as HHSD or AW, and referrals from other regulatory agencies such as TCEQ or LCRA.

SCRP investigators attempt to obtain voluntary compliance with applicable water quality regulations when violations are found. If unable to obtain voluntary compliance with City regulations, WPD staff has the option of filing complaints against the responsible party(s) in municipal court. Uncooperative offenders are sometimes referred to the TCEQ or EPA for enforcement as well. Criminal investigations where necessary are referred to Travis County Attorney's Office. Ultimate enforcement may be through one or more City departments or external agencies as their jurisdictions apply. Investigators in this program work with a large number of regulatory entities, including interactions with government organizations at the federal, state, county and local level.

Integrated Pest Management (IPM) Program

In order to reduce the discharge of pollutants related to the storage and application of pesticide, herbicide and fertilizers, Austin uses an Integrated Pest Management (IPM) Program. The IPM Program implements an IPM public education campaign; administers an internal IPM Program; and reviews IPM plans required for private development projects in environmentally sensitive areas.

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The primary focus of the City's IPM public education program is to provide information related to IPM principles and practices and non-point source pollution that may result from improper fertilizing and pest management practices. Program staff also provides information related to specific IPM products, general water quality, wet ponds, xeriscaping and erosion control practices. Information is disseminated through various means such as printed materials, including posters, bookmarks and brochures; public services announcements; billboards; one-on-one phone conversations; and presentations to community and professional organizations. Staff provides printed materials related to IPM, non-point source pollution and proper fertilizing practices to local gardening centers, City libraries and various other locations in the Austin area for distribution to the general public. See www.growgreen.org and the Excess Nutrients Watershed Profile for more information.

The focus of the internal City of Austin IPM program is the development of IPM plans for departments that require frequent application of pesticides, herbicides, or fertilizers. Each departmental IPM plan is reviewed by IPM program staff and must include at minimum, the standard language and measures found in the model pest management plans as amended or updated by program staff.

As stated previously, the City of Austin Land Development Code requires any development project such as public and private parks, golf courses, open spaces and residential or commercial developments, to prepare and submit an IPM plan for the proposed development if it is to occur within identified environmentally sensitive areas of watersheds within the City's planning jurisdiction. The IPM program staff review proposed private IPM plans for the minimum pollution prevention and source control measures outlined in the City of Austin Environmental Criteria Manual and provide approval. IPM program components required by the Environmental Criteria Manual include:

- Lists of any pests (insects, mammals, plant disease, weeds, etc.) anticipated to require control
- For each pest, a hierarchy of treatments must be developed beginning with cultural, mechanical, biological and other non-toxic controls and ending with chemical control.
- A description of the monitoring plan, damage level or other method to be used to determine when treatments are necessary
- A list of control products included in the hierarchies, identified by active ingredients and toxicity class, if necessary
- A description of the project for which the plan has been developed (commercial, residential, etc.), including approximate acreage of each landscape type(s) (i.e., turf, ornamental, etc.)
- A list of any watercourse, creek, spring, pond, storm sewer inlet, sinkhole, cave or fault within 150 feet of the area to be maintained. Fifty to 150 foot pesticide and fertilizer setbacks from these features are required.

Structural Stormwater Controls

Structural water quality controls may consist of engineered and constructed filters, chambers, basins, or ponds which are designed to treat stormwater runoff by settling, filtration, flotation, absorption, and/or biological processes. The Land Development Code establishes the need for structural controls to enhance water quality and the Environmental Criteria Manual provides guidelines for both the design and long-term maintenance of these facilities. Structural controls include: biofiltration, porous pavement, rain gardens, rainwater harvesting, retention irrigation ponds, sedimentation filtration ponds, vegetated filter strips, and wet ponds.

Sedimentation/filtration systems are the primary stormwater treatment device used in Austin. Runoff is first diverted into a sedimentation basin, where particulate pollutants are removed via gravity settling, followed by filtration through an 18” layer of sand. These systems can achieve removal rates of 40-90% for suspended solids, heavy metals, and organics, including 80% removal of lead and zinc. The other types of controls listed above would provide at least an equivalent level of treatment, with SOS-compliant ponds such as retention irrigation removing up to 100% of suspended solids, heavy metals, and organics.

8.4 Case Studies

Rosewood Remediation

Rosewood is an environmental remediation project in the Homewood Heights neighborhood involving a 2.3 acre property located behind 32 private residences and lots on Ridgeway Drive, Sol Wilson Avenue and Pandora Street. The property is owned by the City of Austin Watershed Protection Department. There is a commercially zoned private property to the south. The plat maps indicate the site is designated for stormwater drainage purposes and for park use.

In April 2007, based on a citizen request to keep the area cleaned and better maintained for citizen use, the City found and removed 25 truckloads of household trash and construction/demolition debris from the city property. Through removal of the trash and debris, City staff uncovered burned material and ash including broken glass and pieces of melted metal which indicated an old dump site existed on the property. This finding raised environmental and health concerns. The property was immediately fenced to prohibit public access. Initial cursory testing showed elevated lead and arsenic levels. The pesticide DDT was also detected. The neighborhood was notified of these initial findings via public notices and presentations at neighborhood association meetings. The burned material could have originated from a variety of sources including, individuals burning household trash or from a larger scale incinerators. This type dump site is commonly found in areas such as this, which were at one time, long ago, outside of the City limits.

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In 2008, an environmental assessment was completed and sampling results verified elevated levels of lead, arsenic and pesticides. The assessment also revealed the waste material was not only dispersed and buried on City property, but on 13 surrounding private properties. The ash material was found buried up to several feet deep in some areas and in one private lot it was 20 feet deep. In 2009, the City obtained an engineering firm to design a remediation plan and to develop bid specifications for a remediation contract. The plan includes the cleanup of the 13 affected private properties due to the potential of the waste material to runoff onto the City property.

Funding for this project comes from the Abandoned Landfills Remediation Fund. This fund was created to investigate and remediate closed and abandoned landfills that the City owned, operated, or disposed of waste at the site or where waste is found on City-owned property. Contributions to the fund come from Austin Resource Recovery, Austin Water, and the Watershed Protection Department.

8.5 Supporting Documentation

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Ingersoll et al. 2001. Predictions of sediment toxicity using consensus-based freshwater sediment quality guidelines. Archives of Environmental Contamination and Toxicology 41:8–21.

Mahler et al. 2005. Parking lot sealcoat: an unrecognized source of urban polycyclic aromatic hydrocarbons. Environmental Science and Technology 39, 5560–5566.

9 Unstable Channels

9.1 Problem Score Calculation

Unstable Channels = 100 – ¾ * bank stability EII – ¼ * channel alteration EII

This score prioritizes anthropogenically-altered reaches that are unstable as problems. Stream morphology responds to watershed stressors of varying types, duration, and magnitude, which may result in degraded surface water quality, damaged structures, loss of amenity values, and diminished habitat.

The impacts of urbanization on channel erosion have been documented in the literature since the early 1970s. The effect of covering land surfaces with impervious materials is increased stormwater runoff, decreases in overland sediment yield, increases in channel sediment transport, and subsequent channel enlargement through incision and widening. Channel erosion due to urbanization can then become the predominant source of excess sediment in downstream receiving waters and degrade biotic integrity.

Investigators from various regions in the U.S. have reported that channel instability and abrupt declines in indices of aquatic ecosystem integrity are frequently observed at 10 to 20% watershed imperviousness. Even lower levels of urban development can cause significant degradation in sensitive water bodies. Impervious cover levels of 35% are associated with 4-fold increases in the 2-year flood that doubles erosion of the stream bed and banks, leading to public and private property loss.

Since stream channel geometry is highly correlated to the 2-year discharge, it is expected that increases impervious cover will have a significant effect on channel stability. Although a quantitative relationship between imperviousness and magnitude of channel response is not consistent across all watersheds and channel types, the trend towards channel enlargement is predominant. The onset and rate of channel enlargement is highly dependent on geomorphic thresholds and soil structure associated with the channel boundaries. Regardless, numerous studies throughout the US and Texas demonstrate that channels frequently enlarge in area by more than a factor of 2 due to the effects of urbanization. Additional studies conducted by the City of Austin have demonstrated potential increases in channel area by a factor of 10 in highly impervious watersheds with alluvial streams.

9.2 Base Map

The Base Map is an ArcGIS document that organizes and displays data related to unstable channels, including both potential sources (e.g., modified channels, steep slopes) and potential solutions (e.g., erosion projects, riparian zone restoration). The purpose of the Base Map is not only to provide

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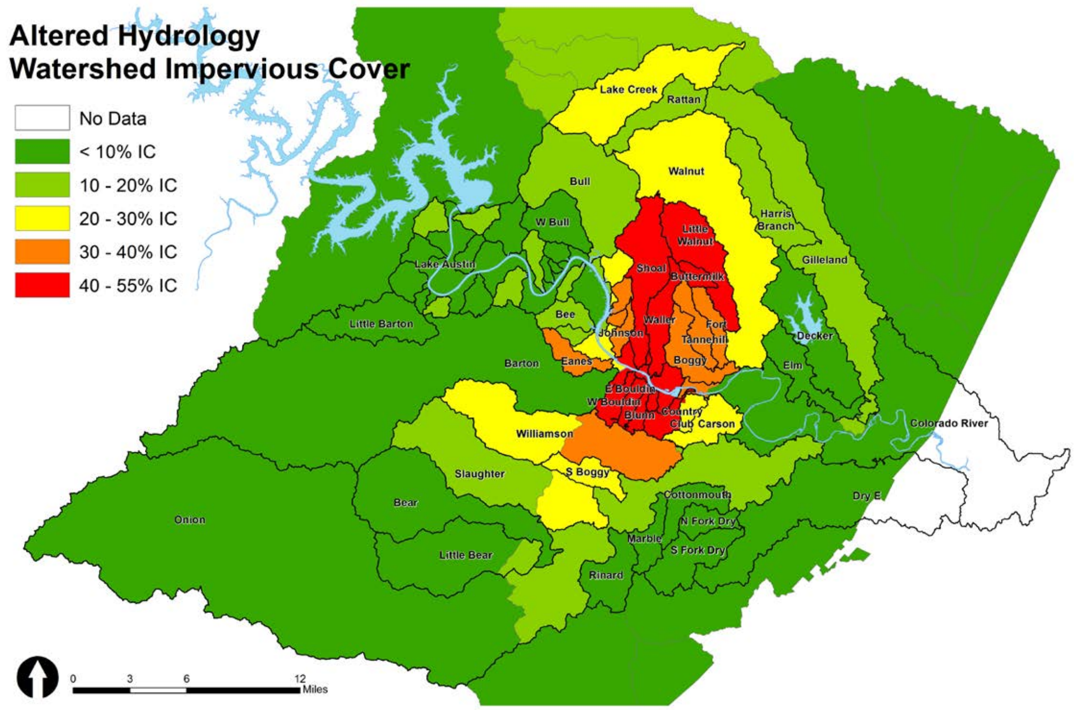
a clearinghouse of related data, but also to allow staff to spatially correlate potential sources and solutions with the problem scores for individual EII reaches.

This data was identified through meetings with internal department stakeholders and is a combination of existing GIS data as well as newly-created GIS data. Upon completion, the Base Map was reviewed by the internal stakeholders and additional updates were completed.



9.3 Actions

Introduction

The Watershed Protection Department addresses water quality degradation associated with unstable channels using a three-tiered approach of programs, regulations, and capital improvement projects.

Examples of programmatic solutions include passive restoration projects and maintenance practices. These programs are discussed in more detail in the Poor Riparian Vegetation Watershed Profile. Examples of regulatory solutions include requirements for impervious cover limits, structural stormwater controls, and erosion hazard zone setbacks. For a more detailed discussion of impervious cover limits and hydrologic controls, see the Altered Hydrology Watershed Profile. Examples of capital improvement projects include stream stabilization projects as well as riparian restoration projects. Riparian restoration techniques are discussed in more detail in the Poor Riparian Vegetation Watershed Profile.

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Stream Stabilization Projects

For over a decade, the City of Austin has been a leading agency in developing and implementing bioengineering and stream restoration practices that provide stable stream systems, improve habitat, and retain the natural character of Austin's waterways. To combat increased erosion impacts, stream restoration engineers implement sustainable solutions through capital and in-house construction projects (see Fort Branch Case Study below). Services of the Stream Restoration Program include:

- Erosion Assessments: Assessing stream erosion, stream reach conditions and documenting threatened properties and public infrastructure.
- Planning: Prioritizing erosion problems, project selection, and solution development.
- Implementation: Stream Restoration staff prepares in-house erosion repair designs/plans for two WPD Field Operations crews and implements Capital Improvement Projects funded through the Drainage Utility fee.
- Technical Assistance: SRP staff provides technical assistance on stream erosion and restoration to other City departments and the private sector.

The intent of erosion protection is to create a channel that will withstand hydraulic forces, yet provide a pleasing, natural appearance. The design approach will anticipate maximizing the use of natural materials and/or providing screening (with natural materials) of any man-made materials that might be used. For inundated areas that will not support vegetation, such as the riverbed and lower banks of the pilot channel, it is assumed that native limestone will be the preferred material.

Bank stabilization methods will be based upon hydraulic shear, which relates to erosion potential. Pilot channel and floodway bank treatments at a particular section may change with height up the bank, as shear varies with depth of flow. Toe of slope protection for bank stabilization will extend to a calculated depth of potential scour and long-term degradation. Also, bank protection will be keyed into the channel boundary at termination points to prevent flanking.

Common techniques used throughout Austin by the Watershed Protection Department and the most applicable conditions include:

- Vegetative Treatments - milder slopes, lower hydraulic shear stresses.
- Bioengineered Reinforced Earth Systems - steeper slopes with or without limestone boulders at the toe of slope depending on the magnitude and vertical distribution of hydraulic shear forces.

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- Rock Boulder Walls - with joint plantings in steep slope areas and hydraulically aggressive environments that persist to the top of slope.

The first step in consideration of a stream stabilization project includes a site investigation or field reconnaissance where an assessment of stream conditions and the problem severity are made.

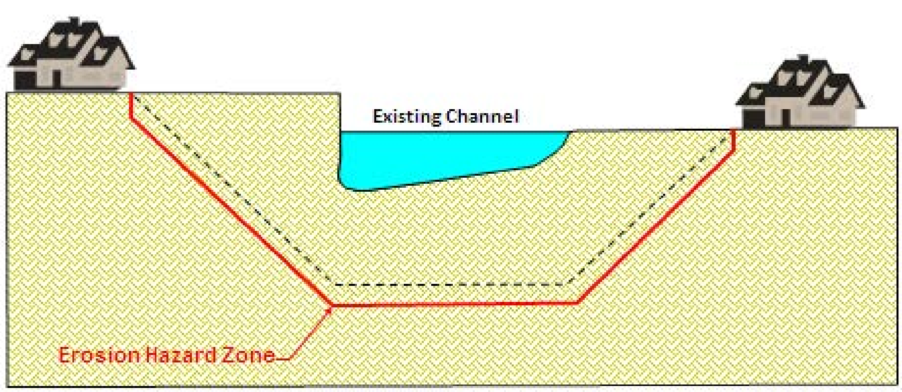
The stream assessment is used to determine the key factors causing the stream instability. This identification may be used to assess whether a long-term solution may be provided on a site-specific, reach based or watershed-scale approach. Constraints such as budget, land availability, and temporal factors also significantly affect the type of solution envisioned.

Erosion Hazard Zone

Erosion is a ubiquitous occurrence and often resources become threatened due to stream bank erosion, slope failure, gully formation, channel down-cutting, or widening. These erosion processes are often unanticipated accelerated with land use changes. The City of Austin spends millions of dollars to stabilize channels where houses, fences, streets, utility lines, and other resources that are threatened by erosion (see Stream Stabilization Projects above).

In most cases, determination of an Erosion Hazard Zone based on anticipated channel changes would have protected these resources from harm. Therefore, the City of Austin has developed a procedure to delineate an Erosion Hazard Zone boundary along waterways outside of which resources should be located to avoid potential impacts of erosion. In this context, a "resource" may be inclusive of roads, buildings, fences, utilities, improved trails, other infrastructure, or any feature of appreciable value.

The Erosion Hazard Zone (EHZ) is defined as an area where stream channel erosion is likely to result in damage to or loss of property, buildings, infrastructure, utilities, or other valued resources. An Erosion Hazard Zone provides a boundary outside of which resources are not expected to be threatened as a result of future stream erosion.



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A ‘Level 1’ analysis is used to predict an Erosion Hazard Zone that is considered sufficient without a high level of site-specific hydrologic, soil, and geomorphic information. This analysis was developed based on observed erosion rates in Austin. An applicant may opt to perform a ‘Level 2’ analysis using more robust technical procedures and detailed site-specific information, as approved by WPD. The Level 2 methodology may account for the time variant rate of erosion considering hydrology, soils, and channel geomorphology over a 30-year period. Observations indicate that the majority of the channel incision process occurs within this time period and risk analyses of uncertainty forecasts often use 30 years as a standard for predicting long-term erosion.

Although it is preferable to set all development outside of the natural Erosion Hazard Zone, the limits of the Erosion Hazard Zone can be revised where protective works are provided. Stream bank stabilization for this purpose should be designed to withstand the 100-year flood event. Bioengineering and stream restoration practices that preserve the natural and traditional character of the riparian zone are encouraged. In cases where the Erosion Hazard Zone cannot be avoided or revised via channel stabilization, the structural design of proposed improvements within the EHZ boundary must be adequate to withstand loadings for the eroded conditions during the 100-year flood event and not create a public health and safety hazard if exposed. Stream stabilization and protected features within the Erosion Hazard Zone must comply with all other LDC requirements and shall not create adverse impact by redirecting flow, reducing conveyance, collecting debris, degrading water quality, or damaging ecological health in the riparian zone.

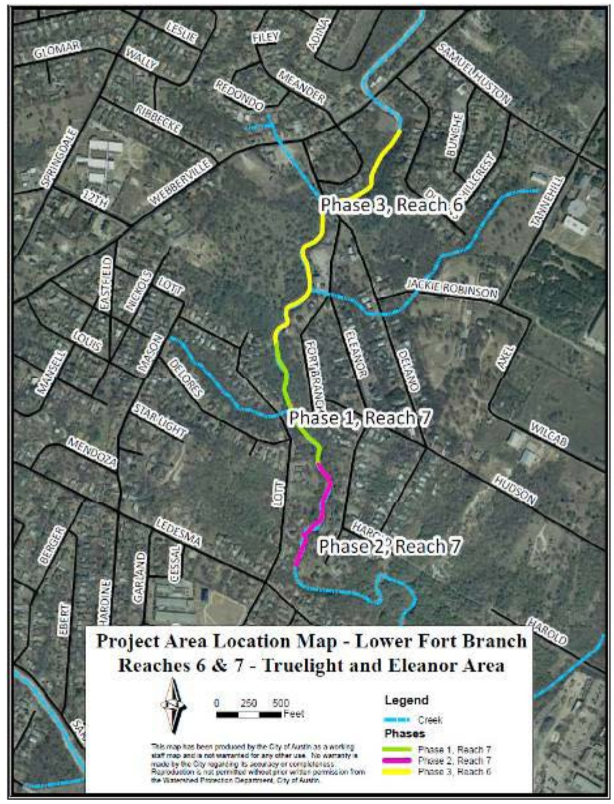
9.4 Case Studies

Fort Branch Stream Stabilization

This channel rehabilitation project is located along Fort Branch Creek, from Fort Branch Boulevard south to just beyond the Eleanor Street cul-de-sac. It uses an integrated approach to resolve flooding, erosion, and habitat degradation problems while improving water quality along about one mile of Fort Branch Creek. This large project is being constructed in three phases and spans two stream reaches, Reach 6 and Reach 7.

Components of this project include:

- Purchasing some flood-prone properties that are immediately adjacent to the creek.
- Stabilizing approximately 2,750 feet of stream banks with mechanically stabilized earth
- Channel modifications for reduction of flooding along approximately 1,600 feet of creek.
- Revegetation along banks with native plant species.
- Construction of a new bridge on Fort Branch Boulevard and removal of culverts.
- Storm drain upgrades



9.5 Supporting Documentation

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Morisawa, M., and E. Laflure. 1979. Hydraulic geometry, stream equilibrium and urbanization. In: Rhodes, D.D., Williams, G.P. (Eds.), Adjustments of the Fluvial System. Kendall-Hunt, Dubuque, Iowa, pp. 333–350.

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Appendix D

1 Status of 2001 Program Recommendations

Appendix D Table 1.1-1 Current Status of 2001 and Other Earlier Master Plan Program Recommendations

2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Flood Early Warning System	1) Develop a plan to enhance emergency preparedness planning, decision support and response tools. 2) Coordinate activities and support Project Impact (federal program to build disaster resistant communities). 3) Integrate improved H&H modeling and flood plain mapping into FEWS. 4) Enhance data sharing and coordinate flood warning activities with the National Weather Service and other agencies.	FM	Flood Early Warning System (FEWS)	**Ongoing.** 1.5 FTEs (Full Time Employees) added in Fiscal Year (FY) 05. 1) Implementing improvement recommendations from FEWS Evaluation Study for Flood Forecast Modeling and Kisters Data Management System. 2) Updated Combined Transportation, Emergency & Communications Center (CTECC) equipment. Coordinating with CTECC on Disaster Planning. 3) Implementing FEWS Evaluation Study, implementing predictive inundation mapping. 4) Implemented through partnerships with the National Weather Service, LCRA, and WCIDs.
Flood Hazard Public Information	1) Additional staff to improve current customer service levels. 2) Enhance planning and implementation of direct public education regarding a) flood hazards b) floodplain mapping c) flood plain development regulations & procedures d) National Flood Insurance Program. 3) Coordinate with and support Project Impact.	FM	FEWS + Floodplain Management, assisted by WPD PIO Community Services	**Completed.** 1) 1 FTE added in FY 06 that is funded through the Flood Plain Office. 2) Flood Safety Awareness Week activities implemented, public support for adoption of new floodplain maps. 3) Project Impact was a grant received and Implemented through the Office of Emergency Management.
Flood Plain Office	1) Additional staff to create Digital Flood Insurance Rate Maps, 2) to provide public notification of changes in floodplain status (flood insurance requirements), 3) and to review development in the floodplain.	FM	Floodplain Management	**Completed.** 1) DFIRM Maps have been updated. 2) Public Notification is now done through a new floodplain mapping program. 3) A position has been located in the One Stop Shop for review of development in the floodplain.

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2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Flood Project Planning, Implementation and Field Engineering	Additional staff to meet essential performance levels. Services need to be completed within a reasonable amount of time, and an inventory of existing storm drain locations is needed.	FM	Local Flood Hazard Mitigation + Field Engineering Services	**Ongoing.** FTEs were reallocated from this program to a new program activity, Field Engineering Services, primarily responsible for providing pond inspection services, utility location, FEMA Creek crossing inspection drainage easement acquisition/releases, and to assure proper functioning of drainage systems. The Drainage Infrastructure GIS (DIG) is ongoing and will provide the inventory of existing storm drain locations.
Storm Drain System Cleaning	1) Identify and target areas with high debris collection for regular maintenance. 2) Inventory expanding as annexation occurs and commitments for storm drain cleaning are mandated in service plans.	FM	Storm Drain Rehabilitation	**Ongoing.** Added 1.75 FTE to the storm drain crew and 2 FTEs to the concrete crew. 1) Target area list maintained and mapped to schedule areas relative to areas with high frequency flooding. 2) Staffing needs continue to be evaluated relative to demand.
Storm Drain System Repair and Rehabilitation	1) Additional staff to provide an improved level of service. Currently, approximately one-tenth of needed repairs are performed each year. 2) Develop a method to track storm drain condition and age to allow for systematic replacement.	FM	Storm Drain Rehabilitation + Infrastructure Inspection	**Ongoing.** Added 1 FTE (2006). DIG program and Work Order Management System (WOMS) will partially address needs identified. Need to reevaluate based on these new efforts. In 2012 a new program was identified for TV inspection crew and expanded to create 2 inspection crews to assist in tracking age & condition.
Watershed Management and Facilities Planning	Additional staff to perform engineering assessments and preliminary engineering, provide project planning and design for large-scale projects.	FM	Stormwater Management	**Completed.** Added 2 FTEs in FY 06 to Flood Hazard Mitigation, added 1 FTE to coordinate projects for bond funding in FY 08, added one position to jointly assist both programs in FY 12.

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2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Watershed Hydrologic and Hydraulic Modeling and Flood Plain Mapping	Additional staff and contractual funding is needed for 1) implementation of a systematic model maintenance and 2) upgrade procedure for the existing watershed models; and for 3) development of an efficient digital model storage and retrieval system.	FM	Floodplain Management	**Completed.** 1) 1 FTE added in FY 06 for floodplain mapping. 2) New floodplain studies have been completed for much of the city. Refer to Section 4 for details. 3) This project is complete.
Dry Weather Field Screening	New program to conduct screening required by federal permit. Dry weather field screening and inspection of storm drain outlets must be performed to locate and eliminate illicit non-storm discharges. By monitoring during dry weather, illegal and problematic discharges can be detected, traced and disconnected to prevent pollution of creeks. Work to be performed by existing City staff.	WQP	Included as a function of Inter-governmental Compliance program	**Completed.** Added dry weather screening to current monitoring using existing staff in FY 03; no FTEs added for this purpose. Met requirements for NPDES permit.
Water Quality Control Planning and Implementation	Additional staff are needed to implement expanded WQ retrofit program.	WQ	Stormwater Treatment + Stream Restoration	**Completed.** Reclassified existing positions in conjunction with reorganization to combine water quality planning and stream restoration to more fully utilize existing staff has addressed this need.
Environmental Impact Assessments	1) Require Citywide Capital projects to make environmental assessment reviews early in the design process. 2) Expand hydrogeological review to support growing WPAP review needs, cave management plan review/coordination, and karst feature protection and mitigation reviews. 3) Expand hydrogeological and biological review capabilities to account for additional Capital projects environmental assessments for review.	WQ	Surfacewater Evaluation + Groundwater Evaluation + Endangered Salamander Protection	**Ongoing.** 1) WPD MIP process for capital projects has addressed this enhancement for WPD projects. ECM revisions adopted for EA standards address this for other departments. WPD working with other City departments on key projects to compile needed environmental information prior to project design. 2) ECM revisions for EA standards complete this recommendation. 3) Hired additional staff (2 FTEs plus temporary staff) to expand review capabilities.

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2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Land Use and Structural Controls Water Quality Monitoring	Coordinate more effectively with users of data. Refocus to monitoring of alternative water quality controls and micro controls.	WQ	Stormwater Quality Evaluation	**Ongoing.** Completed monitoring rainwater harvesting, vegetative swales, retention re-irrigation, and green roof systems. Ongoing monitoring of rain gardens and biofiltration controls.
Rural Watershed Restoration	Proposed new program staff to encourage and provide assistance to local landowners willing to restore degraded rangeland areas. Generally applicable in the undeveloped ranchlands on the periphery of urbanized Austin. Best employed in conjunction with conservation easements, land acquisition, endangered species protection regulations, and other measures to promote water quality protection and baseflow enhancement.	WQ	AW Wildlands program	**Partially Completed.** This new program need has been partially addressed by AW management of environmentally sensitive lands acquired though land purchases and easements primarily through bond monies. Coalitions such as the Barton Springs Zone (BSZ) Regional Plan and the Blackland Research and Extension Center (TAMU)/Central Texas Stream Team (Lower Colorado River Authority, COA, Natural Resources Conservation Services) of which the COA is a participant, also help address this program need.
Contaminated Site Cleanup	Develop a procedure to assign cleanup costs to identifiable responsible parties.	WQ	Included as a function of Environmental Policy	**Completed.** Performance measures for program have been added that calculates pollutants removed.
Storm Drain Discharge Permits	1) Additional staff to address increased workload. 2) Continue development of interlocal agreements to address jurisdictional and regulatory issues. 3) Improve coordination of efforts with the Land Use Review and Environmental Inspection. 4) Upgrade and improve design of database. 5) Research/test pollutant levels of typical discharges.	WQ	Stormwater Compliance	**Ongoing.** 1) Staff need identified in long-range business plan. 2) Service agreement with AW, AFD amendment underway. 3) Working with plumbing plan reviewers regarding problem discharges. 4) Upgrade of database in progress, will be implemented as part of Maximo upgrade. 5) Scheduled for future implementation.

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2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Small Scale Retrofits for Water Quality and Baseflow Enhancement	Create a program to intercept and retain pollutants from nonpoint sources which promote enhancement of stormwater infiltration and baseflow. Widespread implementation of smaller-scale BMPs (usually retrofits) in areas where larger CIP projects are not feasible.	WQ	Joint effort by existing Stormwater Treatment and Water Resources Evaluation Programs	**Ongoing.** Implementing this function with existing workgroups: Stormwater Treatment and Water Resources Evaluation. Studies completed & ongoing in numerous watersheds investigating retrofit opportunities. CIP projects installed rain gardens in Stacy Park, One Texas Center, and Rio Grande streets receiving previously untreated runoff from adjacent land. CIP funding in the 5-year CIP plan to continue retrofitting green stormwater infrastructure (GSI) into City facilities. Ongoing coordination with the Green Streets program within Public Works incorporating green design into street reconstruction projects. Green Stormwater Infrastructure Team identified opportunities for the application of GSI in COA-sponsored retrofits, private development, and voluntary homeowner projects, and to create a common body of knowledge regarding GSI technology, regulations, and community acceptance for WPD and COA. Recent Environmental Criteria Manual (ECM) revisions provide standards for alternative water quality controls.
Emergency Spills and Complaints	1) Additional staff to address increased workload. 2) Continue development of Interlocal agreements to improve communication and address jurisdictional and regulatory issues. 3) Upgrade and improve design of database, and obtain adequate support of database. 4) Achieve better coordination and training of other City Departments.	WQ	Stormwater Compliance	**Ongoing.** 1) 1 FTE added in FY 08 to expand Spills and Complaints Response program mandated by Federal Stormwater regulations. 2) Ongoing effort to address interlocal and interdepartmental agreements. 3) Upgrade of the database is in progress to be implemented with Maximo upgrade. 4) Ongoing effort.

2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Water Quality Assessments	1) Additional staff to continue integration of water quality monitoring database with GIS. 2) Design and implement more monitoring of onsite wastewater treatment/disposal system in cooperation with AW. 3) Evaluate impact of leaking sewers on surface and groundwater quality. 4) Evaluate impacts of development policies on Edwards Aquifer and complete NPDES karst mapping requirement. 5) Evaluate accumulated aquatic biological data with refined watershed characteristics and development history data. 6) Support AW and PARD in managing Hydrilla in Lake Austin to protect water quality downstream.	WQ	Surfacewater Evaluation + Groundwater Evaluation + Endangered Salamander Protection + Watershed Modeling and Analysis	**Ongoing.** 1) Database GIS completed by WQ Planning GIS. 2) Conducted by AW until funding expired; added to GIS. Investigations are conducted when sewage is found in EII sampling. Ongoing studies on surface and groundwater impacts by USGS address this need. 3) USGS studies reference above address this need, in conjunction with the AW Clean Water Program. 4) Continued dye tracing studies provide input and expand mapping. NPDES karst mapping is complete. 5) Ongoing process. 6) Monitored since 2000. Interdepartmental task group established to coordinate City response to Hydrilla concern; new methods of control developed resulting in an improved situation regarding Hydrilla.
Underground Storage Tanks	1) Stagger permit renewals, 2) enhance coordination with SSDP program, 3) upgrade database (currently underway) and 4) integrate UST permit with site permitting process.	WQ	Included as a function of Environmental Review	**Completed.** 1) FY 04 staggering of permit renewals began with issuance of new permits. 2), 3), and 4) completed in FY 03; all HMIs now reviewed. Both a historic and current database and GIS files have been created to store UST records.
Grow Green Program for Water Quality Education	Proposed new water quality education program to promote landscaping practices that protect Austin's environment. Integrates the City of Austin's various landscaping programs, and provides community with one educational source for environmentally-sound solutions to their gardening needs.	WQ	Watershed Education	**Completed.** Completed in FY 03 as part of the Watershed Education Program through launching the Green Garden initiative. Additional FTEs added; see also the Watershed Education program recommendations.

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2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Water Quality Public Education	Additional staff for graphic design, printing, representation at environmental fairs, and to conduct surveys regarding the effectiveness of the public education initiative.	WQ	Watershed Education	**Completed.** Additional staff added to program. Other program enhancements include: Scoop-the-Poop campaign to address water quality problems from animal waste; a Clean Creek Campus outreach program developed jointly with Keep Austin Beautiful (KAB) to provide public education to elementary school children; and an invasive species removal and educational campaign initiated in conjunction with KAB creek cleaning programs supplementing the ongoing Earth Camp program for elementary age children. Created an interdepartmental Green City initiative to coordinate departmental Green City efforts, and an EPA grant administered through TCEQ has been awarded to provide additional Pesticide Prevention Public Education.
Trash and Debris Control Team	New program recommended to target cleanup of trash dumped in City waterways, which often results in citizen complaints and aesthetic problems in creeks and lakes.	INT	Function of Vegetation and Land Management; works with Watershed Education and Lady Bird Lake Maintenance	**Partially Completed.** Enhancement being addressed by existing field operation resources. Ongoing Coordination between APD and Community Court for downtown Waller Creek area. Waller Creek Tunnel operations will include a plan to address trash. Ongoing coordination with KAB, Watershed Education, and Field Operations to address citizen complaints. KAB and Watershed Education coordinate creek cleanups, including invasive species removal and education. Current Field Operations budget includes trash and debris removal from Lady Bird Lake.

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2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Bridge and Culvert Clearing	Assess the level of clogging of structures with assistance from erosion and flood modeling; maintain an updated list of problem areas.	INT	Open Waterway Maintenance	**Completed.** Flood programs evaluate complaint areas for sediment buildup and maintain a problem list. Bridge & Culvert Clearing then work with the Stream Restoration Program (erosion mission staff) to evaluate action needed, schedule corresponding maintenance, and feed information back to the flood programs.
Channel Vegetation Control	1) Program expansion including increased funding for program contracts to meet demand and customer requests. 2) Develop a plan to include erosion concerns when maintenance is planned. 3) Develop a seasonal schedule to avoid contributing to nutrient loading in algae season. 4) Develop a plan to target public expectations of channel maintenance.	INT	Vegetation and Land Management	**Ongoing.** 1) Increased funding in FY 08 for program contracts for vegetation control contracts for ponds and flood mitigation projects, as well as funding for maintenance equipment and tools.2) Work flow developed to allow ERM review of proposed maintenance to gain input from ERM stream stabilization staff on proposed work. 3) ERM staff developed a mowing schedule recommendation to minimize maintenance activities during the growing season to avoid impacting the creek from nutrient loading, and is defining a protocol to provide support to Field Operations toward the implementation of this recommendation. 4) Field Operations working with ERM website development regarding maintenance schedule and public education regarding watershed impacts related to waterway maintenance.
Residential and Commercial Pond Inspections	Additional staff to increase our ability to complete inspections of 480 residential ponds, 3243 commercial ponds, and 852 FEMA creek crossings.	INT	Pond Maintenance	**Ongoing.** Added new FTE in FY 03. Staffing levels will need to continue to be evaluated as additional ponds enter the WPD inventory.

2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Detention and Water Quality Pond Maintenance and Rehabilitation	Current budget measure is 250 of the 480 ponds are maintained annually. All residential ponds are inspected annually and status records are updated.	INT	Pond Maintenance	**Ongoing.** Additional staff (2 new pond crews and inspector) were added in FY 03 to maintain and rehabilitate City ponds. Improved system for tracking newly accepted ponds by City of Austin. Improved pond inspections with 100% of all residential ponds to be inspected starting in FY 02-03. Submitted maintenance and monitoring plan to TCEQ with meetings to discuss BSZ pond inspections.
Flood and Erosion Hazard Property Acquisition	1) Proposed new program would coordinate the voluntary acquisition of properties at risk of flooding and/or erosion. 2) Pursue federal matching grants (Flood Mitigation Assistance Program, Hazard Mitigation Grant Program). 3) Manage acquisition programs, projects and conversion of properties to greenbelts.	INT	Included as a function two programs: Creek Flood Hazard Mitigation + Stream Restoration	**Completed.** Buyouts ongoing using existing Creek Flood Hazard Mitigation and Stream Restoration WPD programs. Contract with outside Real Estate Services initiated in 2008 to expedite buyouts. Management of acquisition property to be coordinated through the Imagine Austin Green Infrastructure Priority program.
Erosion Control Crew	Need additional staff to help reduce the significant backlog of necessary erosion repairs within a reasonable timeframe. The one Erosion Repair crew averages 10 projects completed annually.	INT	Erosion Repair	**Completed.** Added 6 FTEs in FY 06 for a new erosion crew to address backlog of approximately 200 jobs that could be done most cost-effectively in-house. A ranking/ prioritization process is being established to address backload and address highest priority areas first.
Erosion Project Planning, Implementation and Field Engineering	Additional staff to plan, design, and manage construction projects performed by new Erosion Control Crew and Utility contact for Capital projects.	INT	Stream Restoration	**Completed.** Added 1 FTE in FY 06, 1 FTE in FY 08 to coordinate projects for bond funding, and 1 FTE in 2011 (landscape architect position to provide expertise for stream restoration and vegetation components of BMPs).

2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Conservation Easement and Land Acquisition	Proposed new program to identify, facilitate acquisition of, and maintain strategic land properties in the Master Plan watersheds. Application of this program for riparian buffer acquisition could be coordinated with flood and erosion hazard property acquisition, which would deal with similarly located properties.	INT	AW Wildlands Program	**Ongoing.** Additional new staff added in Austin Water (AW) where the management and restoration responsibilities reside. Land management plans for water quality protection completed. Land purchases and easements acquired by use of AW funds and bond monies.
Town Lake Cleanup	Enhance public education with anti-littering campaign.	INT	Lady Bird Lake Maintenance	**Ongoing.** Field Operations now coordinates with KAB and PARD through public education and voluntary cleanup program.
Open Waterway Maintenance	Evaluate channel dredging and sediment removal techniques. Coordination with erosion and flood staff to evaluate the level of sediment accumulation warranting removal.	INT	Vegetation and Land Management	**Ongoing.** Work flow process developed between Stream Restoration and this program to allow review of proposed open channel maintenance work; work plan to be established that protects the stream channel. Success to be monitored over time.
GIS and Database Management	Additional staff for the design and maintenance of database systems, and to provide GIS support for maintenance activities of the department.	INT	Data Management	**Completed.** Data Management section provides database and GIS support the department and oversees completion of the Drainage Infrastructure GIS (DIG). Increased funding in FY 08 for temporary employees to implement DIG, which is nearing completion. The Information Management Plan and Work Order Management System (WOMS) Plan were launched and are underway. Additional GIS support still resides within each mission to meet specific division GIS needs. Departmentwide GIS services also reside within Policy & Planning; 1 FTE added in FY 08 plus numerous temporary positions. These changes have significantly expanded the GIS capabilities of the department.

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2001 Program Name	2001 Phase 1 Program Enhancement	Mission*	2015 WPD Program Name	2015 Status of Recommendation
Pond Operating Permits	1) Improve program to include other watersheds and 2) increase pond tracking through a registration requirement.	INT	Included as a function of Environmental Inspection (OSS)	**Completed.** 1) Pond operating permit program still limited to BSZ watersheds. However, 2) pond tracking greatly improved through a complete overhaul of the Pond Geodatabase and process improvements with the Pond Inspection group within Field Operations. WQ Planning GIS section has developed a database of ponds citywide.
Pond Vegetation Control	1) Increase VCP contract with Easter Seals to provide vegetation control for increasing inventory of ponds. 2) Other enhancements include evaluation of vegetation removal frequencies and methods.	INT	Pond Maintenance	**Ongoing.** 1) Have evaluated and adjusted Easter Seals mowing schedules and methods. 2) Contracter funded to manage need with specialized maintenance provisions to be developed. Success to be monitored over time.
Review and Inspection of Development	Additional staff to upgrade environmental inspection and enforcement capabilities, improve customer assistance services, and consultation on legal matters.	INT	Development Services Department	**Ongoing.** While some additional staff has been added, this needs to be continually evaluated relative to work load and staff training needs. Improvements have been made to the Development Assistance Center to improve customer assistance.
Watershed Master Planning	Phase 2 funding necessary for watershed assessments	INT	Master Planning	**Ongoing.** Revised flood studies completed for 14 Phase 1 watersheds and new studies for 12 Phase 2 watersheds. Erosion studies completed for all Phase 1 watersheds and 14 Phase 2 watersheds. Water Quality EII data available for all Phase 1 & 2 watersheds. See Sections 4, 6, and 7 for detailed information.

**Primary Missions: FM = Flood Mitigation, EC = Erosion Control, WQ = Water Quality Protection, INT = Integrated*

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Appendix E

1 Status of 2001 Regulatory Recommendations

Appendix E Table 1.1-1 Current Status of 2001 and Other Earlier Master Plan Regulatory Recommendations

Proposed Regulation		Description	Category	Location of Modification	2015 Status of Recommendation
1.	Water Quality (WQ) Control Registration	Current requirements exist for operating and maintenance permits for WQ controls in the Barton Springs Zone. Expand registration of WQ controls citywide as a prerequisite for getting reductions in Drainage Charge to help track location and ownership of controls. Actively publicize fee reduction/registration program.	Infrastructure Management	Internal policy process	Completed. Created drainage registration system for drainage controls ("ponds"). Mailout sent to eligible utility customers to advertise the registration. Controls registered receive 20% discount on Drainage Charge if control maintained to COA standards. The Pond Inspection program monitors and removes the discount for non-compliant ponds. Extension of BSZ Operating Permit system no longer necessary and not recommended.
2.	Stormwater Control Inspection and Maintenance	Recommendation post-2001 Phase 1 Master Plan. Code requirements for inspection and maintenance of stormwater controls need to reflect best practices and clarify responsibilities.	Infrastructure Management	LDC 25-7-153, 25-8-231, 30-4-153 & 30-5-231	Completed. Code amended in 2009 to reflect national best practices for a 3-year inspection cycle for water quality and flood structural controls.
3.	Revise Regional Stormwater Management Program (RSMP)	RSMP fee amounts not revised since program began in 1980s. Payment system needs to address increases in land and construction costs while low enough to encourage participation.	Infrastructure Management	Annual Fee Ordinance, DCM	Completed. Fee structure revised.
4.	Revise Urban Water Quality Control Fee (Payment)	Payment-in-lieu amounts not revised since 1990. Payment system needs to address increases in land and construction costs while low enough to encourage participation. Need to also establish participation criteria.	Infrastructure Management	Annual Fee Ordinance; ECM 1.6.4; ECM Appendix T	Completed. Payment system revised, pegged to inflation. Participation criteria added to Environmental Criteria Manual (ECM) in 2002.

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Proposed Regulation		Description	Category	Location of Modification	2015 Status of Recommendation
5.	Drainage System and Waterway Maintenance Criteria	Regulation to allow the maintenance of drainage easements in the original permitted design configuration and to define conditions warranting vegetation removal in order to adequately convey stormwater flows. Set standards for maintenance performed within waterways, including soil stabilization and planting.	Infrastructure Management	ECM/DCM and internal policy	**Completed.** WPD policy established that allows maintenance for channels to the original permitted design configuration. Field Operations division defined conditions that warrant vegetation removal, and standards for maintenance of City-owned drainage easements (see program enhancements). Completed standards for soil stabilization and planting requirements as part of ECM update for erosion & sedimentation controls.
6.	Stormwater Pond Safety	Recommendation to align City requirements with state regulations adopted after the 2001 Phase 1 Master Plan.	Infrastructure Management	DCM 8.3.4	**Completed.** Pond dam safety standards consistent with state standards added to Drainage Criteria Manual (DCM).
7.	Tree Protection and Natural Area Standards	Expand tree protection requirements to allow for specific circumference regulations for different tree species, to require a percent of site be left in a natural area, to protect significant groves of trees, to evaluate establishing a minimum percent canopy cover for a site, and to establish a mitigation fee system for tree replacement.	Problem Prevention	LDC 25-8-602-604, 641-644; 25-2-1007; and 25-2-981, 1031-1035. ECM 3.3.4; 3.5.1; 3.5.4; and Appendix F.	**Completed multiple elements.** Tree ordinance and ECM changes made in 2010: Ordinances to protect heritage tree (24-inches and larger); add trees and landscaping islands to commercial parking lots; add trees to single-family residential subdivisions; Commercial Landscape requirements incentivizing natural area preservation. ECM additions on tree survey requirements; significant tree identification; mitigation fee system; and criteria for tree preservation.
8.	Effluent Irrigation Standards	Require additional soil depth for effluent irrigation; to specify maximum nitrogen loading; to require additional wet weather storage; to require setbacks from watercourses and Critical Environmental Features; and to require monitoring for effluent constituents.	Problem Prevention	N/A	**Not possible.** City of Austin does not have direct authority to regulate land application permits; permits are issued by the State of Texas via TCEQ. WPD participates in individual permit actions and continues to conduct scientific investigations to establish protective permit conditions.

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Proposed Regulation		Description	Category	Location of Modification	2015 Status of Recommendation
9.	Golf Course Management Plan	Require a management plan for all golf courses to include components for water balance, fertilizer loadings and monitoring, and would limit activities in the critical water quality zone.	Problem Prevention	N/A	**No new regulations planned.** But WPD attempts to secure management plans for new or expanded golf courses through settlements with applicants for TCEQ permits for wastewater application or water rights.
10.	Stormwater Detention Design Criteria for Volume Control	Recommendation not originally part of 2001 Phase 1 Master Plan. Ongoing exploration of best means to address code requirement for no downstream adverse flood impact.	Problem Prevention	DCM	Volumetric flood detention criteria to be added to DCM as optional approach. Watershed Protection Ordinance (WPO) added volumetric detention as an option to achieve PUD “superiority” in 2013.
11.	Design Storm Runoff Detention for Stream Bank Erosion	Require developments to capture and detain the runoff volume greater than that released from the undeveloped site for small & relatively frequent storms that control channel size and shape. Smaller storms should be detained for an optimum detention period to prevent erosion damage to property and the stream system.	Problem Prevention	LDC, ECM, DCM	**Completed.** Technical study showed existing water quality capture volume and release rate achieve sufficient downstream bank protection.
12.	Stream Setbacks	Establish erosion-control based stream setbacks to provide property protection from the threat of erosion. Maintain vegetation in the critical water quality zone using native plants without managed turf grass, pesticides, or unapproved fertilizers.	Problem Prevention	Future LDC, DCM, ECM	**Completed** as part of the Watershed Protection Ordinance, adopted by Council in October 2013.
13.	Stream Setback Revision for Colorado River	Colorado River downstream of Longhorn dam insufficiently protected by stream buffers measured from the centerline of River (much of buffer underwater). Critical Water Quality Zones need a method similar to that used for Lake Austin & Lady Bird Lake, measured from bank’s edge.	Problem Prevention	LDC 25-8-92; 30-5-92	**Completed**, adopted by City and County in 2008. Buffers start at bank’s edge, not “stream centerline” as before. Gives proper protection.

	Proposed Regulation	Description	Category	Location of Modification	2015 Status of Recommendation
14.	Drainage Design Criteria	Revise the Drainage Criteria Manual to ensure that new or altered channels are properly designed to minimize future erosion. Potential modification would include adding permissible shear stress criteria for both the bottom and side-slopes for the 1-, 2-, 10-, 25- & 100-year storm events.	Problem Prevention	Standards Manual 508s-16 to 20.	**Complete** with adoption of Storm Drain outfall standards for improved erosion protection. Remaining elements to be addressed in 2014 revisions of Open Channel chapter of DCM.
15.	Lake Austin Shoreline Modification	Substantial portion of Lake Austin shoreline degraded by vertical bulkheads, causing erosion and loss of natural function. Need to prevent further damage.	Problem Prevention	LDC 25-2, Sub. C, Art. 13 & 25-8-92 et al.; ECM 1.13	**Completed.** New Bulkhead Ordinance passed with associated ECM guidance in 2010.
16.	Uniform Relocation Assistance	Address relocation assistance in instances where residential or commercial property threatened by flooding or creek erosion is acquired by the City on a voluntary basis.	Service to Public	LDC 14-3	**Completed.** Uniform relocation requirements adopted based on the Federal Uniform Relocation Act. This process has been utilized for both voluntary and threat of eminent domain buyouts. Due to the volume of buyouts identified after the Oct 2013 floods, a team has been created to bring Code into compliance with SB 18. Additional consideration will be given to designating a separate policy for voluntary buyouts. Rule changes are expected at the end of FY15.
17.	Water Quality Design Criteria	Revise and expand the Environmental Criteria Manual (ECM) to include standard design criteria and assessment methods for alternative water quality controls based on average annual pollutant load reductions.	Service to Public	ECM	**Completed.** See specific subsets listed below.
18.	Alternative Filtration Media	Provide filtration media criteria for biofilters and rain gardens.	Service to Public	ECM 1.6.7.C	**Completed** in 2007. Some additional modifications thereafter.

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Proposed Regulation		Description	Category	Location of Modification	2015 Status of Recommendation
19.	Vegetated Filter Strips	2001-era criteria not based on performance standards expected of other water quality controls.	Service to Public	ECM	**Completed** in 2008. ECM criteria updated for vegetated filter strips.
20.	Retention-Irrigation Criteria	Provide retention-irrigation design criteria for control type used extensively in Barton Springs Zone (No criteria existed in 2001).	Service to Public	ECM	**Completed** in 2004 to add dual pumps and manhole sump requirements. Some additional modifications thereafter.
21.	Rain Gardens	Rain garden option emerging nationally as water quality control; not in 2001-era ECM.	Service to Public	ECM	**Completed** in 2008. ECM criteria updated for rain gardens. Additional implementation options to be considered in Phase 2 of WPO.
22.	Rainwater Harvesting	Rainwater harvesting option not in 2001-era ECM. Has water conservation promise.	Service to Public	ECM	**Completed** in 2008. ECM criteria updated for rainwater harvesting. Additional improvements to be considered in Phase 2 of WPO.
23.	Wet Ponds	Provide wet pond design criteria (No criteria existed in 2000).	Service to Public	ECM	**Completed** in 2000 to add liner, forebay, main pool, vegetation, and other basic design guidelines. Later added water balance requirement for improved conservation and additional adjustments to vegetation types, maintenance access, and reduction in shallow bench area.
24.	Erosion Control-NPDES Permit Provisions	Update City of Austin erosion control criteria to include or reference federal NPDES construction permit requirements, creating a consistent set of criteria for local developers to follow.	Service to Public	ECM 1.4 & Appendices	**Completed** in 2009 to include changes to plan development and implementation, updates to temporary and permanent structural practices, inclusion of special practices, and the requirement for a Storm Water Pollution Prevention Plan (SWPPP). Some additional modifications thereafter.

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Proposed Regulation		Description	Category	Location of Modification	2015 Status of Recommendation
25.	Pollution Attenuation Plan (PAP)	New Master Plan recommendation to support existing LDC references to these standards never included in ECM. Needed to assure water quality addressed when this requirement is triggered by industrial development (e.g., mines and quarries).	Service to Public	ECM 1.3.4	**Completed.** PAP criteria added to ECM in 2009.
26.	Landscape Modifications and LID Design	Modify landscape regulations to allow use of low-impact development (LID) techniques located within landscaped areas. Water quality credit could be offered for such low-impact design alternatives, which include headwater protection. (Also see alternative WQ Design criteria item above.)	Incentive	LDC 25-2-1001 & 1008; ECM 1.6.7	**Completed.** Updated Commercial Landscape ordinance to require a portion of runoff be directed to landscaping and/or protect natural areas in 2010. Added "Green Storm Water Quality Infrastructure" options (rain gardens, rainwater harvesting, porous pavement for pedestrian surfaces, etc.) to ECM, all of which can double to meet landscaping requirements. Additional improvements possible in CodeNEXT revisions.
27.	Erosion Control Site Management	Update ECM to incorporate improvements in materials and design standards. Incentives such as reduction or early release of fiscal could be offered for those using improved site management techniques such as storing and reusing native topsoil, minimizing time between grading & revegetation, use of native or xeriscape plant material and seed mixes, and wash racks to control mud tracking.	Incentive	ECM Appendices P-1, S-1, ECM 1.2 & 1.4; Standard Specs 130S, 601S, 604S, 609S	**Completed** in 2009. ECM revisions include: revision of fiscal surety to include costs for clean-up of fugitive sediment; revisions to erosion & sedimentation control process outline and to construction phasing controls; provides stormwater pollution prevention plan with information for owners, phasing, and construction sequencing. Have not implemented requirements for wash racks or early release of fiscal.

Proposed Regulation		Description	Category	Location of Modification	2015 Status of Recommendation
28.	Development Mitigation Policy	Consider mitigation policies for transfers of development rights so that transfers: (1) result in less impervious cover than otherwise allowed; (2) move development from more environmentally sensitive land to less sensitive land; (3) move development to areas that can be served using existing public infrastructure; and (4) are structured to preserve open space and natural areas within each watershed.	Incentive	LDC 25-8-27; ECM Appendix Q-4	**Completed**. Added 2007 Barton Springs Zone Redevelopment Exception provisions & associated ECM revisions: can redevelop a site and provide offsite mitigation. WPO added Water Supply Watershed Redevelopment Exceptions and new transfer options (for floodplains and environmentally sensitive areas, between site plans) and an on- and off-site mitigation system for floodplain modification requests.
29.	Implementation Strategy: Revisions to Desired Development Zone (DDZ) Code	Overall strategy to address watershed problems and development pressures in the DDZ. Proposed by staff as a potential method for implementation of improved stream setbacks and development mitigation policy. Includes an evaluation of larger headwaters Critical Water Quality Zone buffers, elimination of Water Quality Transition Zone buffers, the calculation of impervious cover using Gross Site instead of Net Site Area within the COA zoning jurisdiction of the COA, and development mitigation options.	Problem Prevention and Incentive	LDC	**Completed** as part of the Watershed Protection Ordinance, adopted by Council in October 2013.

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